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THE ORGANIZATION AND AIMS OF THE AMERICAN GEOPHYSICAL UNION[1]

LOUIS A. BAUER, *Chairman*

I. HISTORICAL

This is the fourth annual meeting of the American Geophysical Union, as such, although on June 24-25, 1919, there was held a preliminary meeting of a tentatively organized "American Section of the proposed International Geophysical Union," then in process of formation under the auspices of the International Research Council, which, as will be recalled, was established in 1918, when the world conflict was drawing to a close. However, the concept of our Union may trace its origin even prior to the formation of the International Research Council and of the present International Geodetic and Geophysical Union. For soon after the establishment of our National Research Council in 1916, the chairman, Dr. Hale, requested the writer to prepare a memorandum respecting provision to be made for certain geophysical sciences. To quote from this memorandum but one sentence germane to our topic today—"It would appear that great opportunities are before us to make our influence felt in the world-sciences, by which are meant those subjects of research which embrace the Earth, or even the Universe, within their legitimate provinces." In subsequent correspondence with Dr. Hale it was suggested that the term "geophysics" be understood to include geodesy, geological physics, meteorology, terrestrial magnetism, terrestrial electricity, seismology, tides and oceanography; and it was recommended that there be formed a special committee of the Council, or a subcommittee of physics dealing specially with "world physical sciences."

To stimulate further interest in the subject, at the joint meeting in 1916 of the American Physical Society and the Section of Physics of the American Association for the Advancement of Science the speaker presented a paper entitled, "Our part in the Advancement of World Physical Sciences."

It will be seen from these references that the general idea was the formation of a body similar in its organization and aims to those

[1] As presented at the opening general session of the annual meeting of the American Geophysical Union at Washington on April 17, 1923, with some slight additions. The review was prepared in compliance with a request made at the closing session of the annual meeting of the American Geophysical Union in 1922, and in answer to inquiries from members as to the precise status of the Union, especially with regard to its origin and development and its present relations to the National Research Council and to the International Geodetic and Geophysical Union.

embodied in the statutes of the present International Union and, in particular, of our own Union. The chief desire as expressed in these early documents was to provide a meeting-ground for those working, more or less independently, on geophysical subjects having points of contact and common interests. This was accomplished later in Great Britain by the appointment in July 1917 of a special committee on geophysics of the British Association for the Advancement of Science.[3]

The council of our National Academy, however, was not yet prepared to recognize the need of a special body for geophysics alone, and considered that the desired object could be attained by merging geophysics with geography, and accordingly four of the present members of the American Geophysical Union became members of the Geography Committee, under the chairmanship of Professor William Morris Davis. But soon after geophysics received a more distinctive recognition, being specifically mentioned in the title of one of the most important divisions of the war organization of the National Research Council, namely, the "Division of Physics, Mathematics, Astronomy and Geophysics." It was the writer's privilege to serve as a member of that division, under the chairmanship of Dr. Robert A. Millikan, throughout our participation in the war.

Then came the close of the war and with it a reorganization of the National Research Council on a peace basis. One of the live questions was how best to secure representative membership for the various divisions: Physical Sciences, Chemistry, Geology, etc. The solution of this problem was comparatively easy for the sciences which had national societies. Thus the Division of Physical Sciences would be recruited from time to time by representatives recommended to the National Research Council by the American Physical Society, the American Astronomical Society, the American Mathematical Society, etc. But how were the geophysicists to be represented? For seismology, there was the Seismological Society of America, and for meteorology, there was at that time in process of formation what has

[3] The British Geophysics Committee had its first meeting in November 1917, in the rooms of the Royal Astronomical Society at Burlington House, London. Since then there have been "Geophysical Meetings" about once a month during each year from about October to May. The topics discussed have covered every branch of geophysics and the leading men of science in Great Britain, interested directly or indirectly in geophysics, have participated. Abstracts of the papers and discussions are published in the British monthly journal, *The Observatory*. Some of the papers have been published in the Geophysical Supplement of the *Monthly Notices of the Royal Astronomical Society*. Three of these "Supplements" have thus far appeared, namely for March 1922, January 1923, and May 1923.

since become the American Meteorological Society. But there were no distinct national societies for geodesy, terrestrial magnetism and atmospheric electricity, volcanology, oceanography, and geophysical-chemistry. To be sure, quite a goodly number of geophysicists were members of the national societies devoted to physics, astronomy, mathematics, geology, and geography. Hence, to a limited degree, representation on a Geophysics Committee of the National Research Council could be obtained from certain existing societies, and the number of representatives thus secured could be supplemented by the National Research Council through choosing members at large, interested in branches of geophysics not distinctly recognized by the existing national societies.

Finally, in February 1919, Dr. Hale, as Chairman of the National Research Council, appointed a small committee to consider the question of the organization of an "American Section of the proposed International Geophysical Union," and the chairman of the committee, Dr. R. S. Woodward made a report, which as it is brief, yet full of interest at the present time, we shall quote here in its entirety:

"MARCH 4, 1919.

"To the Chairman of the National Research Council:

"Your Committee appointed to consider the question of a logical and practicable organization of the proposed American Section of the International Geophysical Union respectfully submits the following report:

"The earth is at once the subject and the object of many sciences. Of these the most important are Astronomy, Geodesy, Geology, Meteorology, Seismology, Terrestrial Magnetism, Terrestrial Electricity, Tides, and Volcanology.

"While each of these sciences is more or less distinct in itself, they are closely related to one another, and progress in any one of them may be expected to depend to a great extent on the general progress attained in the others. Each of these sciences has its devotees and its experts, and the number of these in the aggregate is now very large. Hence in any scheme of effective organisation it is essential to secure groupings of these various subdivisions of geophysics in order that the number of groups may not be too unwieldly in the transaction of business essential to such organizations. But it should be distinctly understood that in recommending a limited number of groups for purposes of administration it is not desired to discourage relations of closest reciprocity between the devotees to the various sciences included in the groups. On the contrary, it is the opinion of your Committee that progress in the future is most likely to result from active cultivation of the borderlands that now serve to distinguish, but only indefinitely, the several fields of geophysics.

"It should be understood also that the groupings recommended are to be regarded as provisional and subject to such changes as future experience may suggest. It is recognised also that the groupings here recommended may not be the most appropriate for all countries or possibly for an international organisation, since much regard should be given in all such matters to historical precedents and to the circumstances presented at any epoch by individual investigators, and especially by governmental organisations, of any country.

"With these reservations the Committee recommends that the following groups

of subjects should be recognised in the organisation of the American Section of the International Geophysical Union:

"Group 1. Geodesy. This group may be assumed to deal with questions concerning the size, the shape and the mechanical properties of the earth.

"Group 2. Seismology and Volcanology.

"Group 3. Meteorology and Mareology, including especially all questions presented by the mechanical properties of the atmosphere and the oceans.

"Group 4. Terrestrial Magnetism and Terrestrial Electricity. This group is intended to deal with the magnetic and the electric properties of the earth, including its atmosphere.

"The Committee recommends that initially the designation of members to constitute the proposed Geophysical Section be made by the National Academy of Sciences. It is further recommended that in making such designations regard be had to the desirability of securing representatives from the following Government Bureaus:

Bureau of Fisheries
Bureau of Mines
Bureau of Standards
Coast and Geodetic Survey
Hydrographic Office, U.S.N.
Geological Survey
Weather Bureau

"Similarly, the Committee suggest that representatives also may be fitly chosen from the following national societies:

American Astronomical Society
American Mathematical Society
American Physical Society
Geological Society of America
Seismological Society of America

"The Committee further recommends that in order to promote research and discovery in geophysical science in general, steps be taken by the American Section of the International Geophysical Union toward the formation of a new society to be called the American Geophysical Society.

(Signed) "R. S. WOODWARD,
"For the Committee."

At a meeting of the Executive Committee of the Division of Physical Sciences, March 10, 1919, the organization and initial membership of an American section on Geophysics were approved, and soon after were also approved by the National Academy of Sciences. The exact designation of subjects to be included in the various groups was deferred, however, until after the Brussels meeting in July 1919 of the International Union. The question of the establishment of a geophysical society was also referred for settlement to the Geophysical Section after its permanent formation. Messrs. William Bowie, Louis A. Bauer and C. F. Marvin were made members of the Division of Physical Sciences to represent Geophysics.

Four meetings of the Provisional Executive Committee of the Geo-

physical Section were held in May and June 1919 and on June 24 and 25 the Section was tentatively organized, Dr. William Bowie acting as chairman. Permanent organization was deferred until after the Brussels meeting. The Section accepted the proposal to be the Geophysics Committee of the Division of Physical Sciences, and decided to concern itself with national as well as international problems in geophysics. At this meeting delegates were appointed to the Brussels meeting and resolutions were passed respecting various matters pertaining to the organization and sections of the proposed International Union. The delegates were also constituted a committee to draft a plan for permanent organization of the American Section after the Brussels meeting.

On November 13, 1919, the secretary of the tentative American Section transmitted to the members "Proposals for the Permanent Organization and Statutes of the American Geophysical Union," prepared by a sub-committee, after giving very careful consideration to the following points: (1) The structure and Statutes of the International Research Council, and of the International Geodetic and Geophysical Union, definitely formed at Brussels in July 1919; (2) the present relations of the existing "American Section of the proposed International Geophysical Union" to the National Research Council, and the relations considered desirable in future; and (3) the views expresseed by present members, especially at an informal conference of the Committee of the Brussels Geophysical Delegates with members of the "American Section" who reside in or near Washington. The said conference was held on October 31, 1919, at the office of the National Research Council. Furthermore, in drafting the "proposals," the sub-committee had the benefit of extended conference with Dr. C. E. Mendenhall, at that time Chairman of the Council's Division of Physical Sciences, and of Dr. Henry S. Washington, both of whom were present at Brussels.

The secretary, Dr. Harry O. Wood, further stated in his transmitting letter:

"The present status of the 'American Section' is that of a *committee* of the Division of Physical Sciences of the National Research Council. This status it will retain until it is discharged as such, or until it is superseded by the adoption, as of some definite date, of proposals for permanent organization which change its status. In this connection it has seemed best to the committee on organization to recommend that the proposed 'American Geophysical Union' be made a Committee of the Council, as a whole, and that the 'Union' be so constituted as to *unite and co-ordinate* in our country the interests of physics, chemistry and geology in geophysical questions.

"The name 'American Geophysical Union' was settled upon as the result of careful consideration and evolution of various preliminary drafts. Thus, instead

of 'Union' it was originally proposed to use the term 'Committee,' and later 'Commission'; however, as progress was made in drawing up the proposals, the need of a more appropriate term became evident. Thus, the 'American Geophysical Union,' as proposed, is a union of two distinct committees, namely, the American 'National Committee' of the International Geodetic and Geophysical Union, and the Committee on Geophysics of the National Research Council. In the absence of an American Geophysical Society in the United States, the proposed 'Union' would seek to bring together and co-ordinate all societies, bodies, and institutions in the United States interested in geophysics."

The "Proposals," having received the unanimous approval of the members composing the former "American Section," were approved by the Executive Board of the National Research Council on December 20, 1919. On February 14, 1920, the American Geophysical Union was made a committee of the Executive Board of the Council, and the first meeting of the Union was held on April 23, 1920. Dr. William Bowie, who had been acting chairman since 1919, was elected chairman of the Union for the statutory two-year period 1920-1922.

II. ORGANIZATION

These introductory remarks will suffice to show the initial difficulties encountered and how, in consequence, there was gradually developed the "American Geophysical Union," which has the unique distinction of being like no other body of the National Research Council. During 1919 and 1920, we were attached to the Division of Physical Sciences as the National Geophysics Committee, just as are the national committees for astronomy, mathematics and radiotelegraphy. However, we proved ourselves too lusty an infant for in membership we outweighed the entire Division. Then again the Council soon found that Geophysics was of so wide a scope that its points of contact were not simply with one division, but with several. And so finally in 1920 we were made one of the Technical Committees under the direct parentage of the Executive Board of the Council. But our woes did not end there, for at that time we had no representative voice on the Board and as the membership of the Board changed from year to year, we suffered the natural consequences resulting from variable parentage. Just as our parent towards the end of his year's membership on the Board would become truly sympathetic with our aims and alive to our needs, he would be succeeded by a new parent and the process of enlisting interest had to be begun all over again.

Fortunately, although our Union, unlike other national bodies and other sciences, still has no direct representation on the Council's Executive Board, it has certain ex-officio members on its Executive Committee; namely, the chairmen of the following divisions of the

Council: Foreign Relations, Physical Sciences, Chemistry and Chemical Technology, Geology and Geography, and Biology and Agriculture. We must depend upon these ex-officio members, who also, in general, vary from year to year, for representation at the meetings of the Executive Board of the Council. During previous years it was only rarely, for one reason or another, that one of the ex-officio members was present at the monthly meetings of our Executive Committee. During the present fiscal year, however, there has been an exceptionally faithful attendance on the part of some of the ex-officio members.

We also, in our entirety, proved too "bulky" as a committee of the Executive Board, especially when it came to the matter of the possible moral obligations involved to provide traveling expenses for every member of the Union coming to the annual meetings. Hence, in the spring of 1921, the relation of the American Geophysical Union to the Council was changed so that the Union as a whole was replaced as the Committee on Geophysics of the Executive Board of the National Research Council by the Executive Committee of the Union. The Union, as a whole, however, continues to be the American National Committee of the International Geodetic and Geophysical Union.[3] Although not every member of our Union is recognized now as a member of the National Research Council, it is the Union as a whole which nominates to the Council the members of the Executive Committee of the Union.

In other words, the American Geophysical Union is now virtually on the same footing as existing national societies, which choose and recommend to the National Research Council their representatives for the various divisions and committees of the Council. While we still recognize the sponsorship of the Council, in that we submit to it for approval any amendments to our statutes or additions to the membership, it is not believed that the Council would interpose any objections if we thought it desirable to form ourselves into a national geophysical society. As has been shown, in many respects we are already essentially such.

According to action taken at the annual meeting in 1922,[4] our permanent membership was limited to 75, subject to future change as circumstances required; there are at present 65 members, widely distributed geographically, even Hawaii being represented.

Whether the time is ripe to constitute ourselves into an "American Geophysical Society," or whether we should retain the present name

[3] See Sixth Annual Report of the National Research Council, p. 6; and minutes of the Executive Committee of the American Geophysical Union, May 7, 1923.

[4] Also confirmed at the annual meeting in 1923.

"American Geophysical Union" and the present organization as indicative of a union or confederation of geophysical sciences, and alter or expand our organization and membership, is a matter for discussion. If we follow the type of organization as represented by a society, we may readily include in the membership citizens of other countries than the United States. In accordance with a recent action taken by the Executive Board of the National Research Council, "membership in the Council shall be limited to citizens of the United States. This, however, shall not be construed as applying to membership on committees appointed by or acting under the Council whose members are not necessarily members of the Council; provided that members not citizens of the United States shall in no case form a majority of any such committee.[5] The majority of our Executive Committee and of chairmen of sections must accordingly be citizens of the United States.

III. OBJECTS

Quoting from the statutes[6] as adopted in 1919 and amended to May 1923:

Preamble.—"The American Geophysical Union is hereby established by the National Research Council. It supersedes the 'American Section of the proposed International Geophysical Union.' The American Geophysical Union is the American National Committee of the International Geodetic and Geophysical Union and the Executive Committee of the American Geophysical Union is the Committee on Geophysics of the National Research Council."

Objects.—(a) To assist in carrying out the objects of the International Geodetic and Geophysical Union, which are: To promote the study of problems concerned with the figure and physics of the Earth; to initiate and co-ordinate researches which depend upon international co-operation, and to provide for their scientific discussion and publication; and to facilitate special researches, such as the comparison of instruments used in different countries.

(b) To promote and co-ordinate the study of the various branches of geodesy and geophysics in the United States of America and its outlying territories."

A review of the work and functions performed by the Union, since its existence, would show that the objects just stated have steadily been kept in mind and that we have taken our part, as fully as circumstances permitted, in the promotion of international and national projects pertaining to geophysics, in general. From time to time we have furnished information solicited by the National Research Council and International Geodetic and Geophysical Union, and have reviewed proposals submitted to us by or through the Council.

The American Geophysical Union may justly lay claim to having

[5] Action of Executive Board of the National Research Council, February 13, 1923.

[6] See pages 24 to 26.

taken a leading part in the initial recognition, at the organization meeting of the International Geodetic and Geophysical Union at Brussels in 1919, of the chief branches of geophysics, and in the establishment of sections pertaining thereto. Prior to the formulation of resolutions passed at the spring meeting in 1919 of our preliminary organization, the International Research Council at first favored the adoption merely of sections of geodesy, meteorology and seismology by the proposed International Geophysical Union. The American delegates, however, acting in accordance with the conclusions reached at the preliminary meetings in Washington, of the "American Section" and on the basis of the information at hand, advocated the immediate establishment of the following sections: Geodesy, Seismology, Meteorology, Terrestrial Magnetism and Electricity, Volcanology, and Oceanography. And the American view finally prevailed at Brussels as the result of various preliminary meetings of our delegates with those from other countries represented. It was a matter of keen regret to the American delegates, as well as to those of other countries, that the briefer and more logical designation, "International Geophysical Union," as originally proposed, was not finally adopted by the International Research Council, in deference to the wishes of one country.

Five members of our Union are at present officers of the International Geodetic and Geophysical Union, viz: Messrs. Bauer, Bowie, Littlehales, Marvin and Washington, and, accordingly they are also members of the Division of Foreign Relations of our National Research Council. Furthermore various members of our Union are members of committees of the sections of the International Union.

In the matter of arousing renewed interest in the scope of geophysical sciences, and in the unusual opportunities for important and fruitful research, our Union has already done much, through its meetings and publications, though more remains to be done. The observational and investigational work in the various branches of geophysics in the United States is being largely done at present by governmental bureaus and certain research institutions, though notable work is to be credited also to investigators connected with some of our universities. It is believed, however, that the endeavor should be made to enlist the help of still more university men, by presenting in as concrete a form as possible definite problems awaiting experimental and theoretical investigation. During the war we were fortunate in the number of university men who found opportunity for their activities and participation in war investigational work pertaining to various branches of geophysics, notably meteorology. But

as soon as the war ended their interests waned and it behooves us to find new ways of re-stimulating them.

IV. FUNDS

The funds required for the maintenance of the American Geophysical Union, especially in connection with the annual meetings, averaging about $1,000 per annum, are provided by the National Research Council. The Council, through its Division of Foreign Relations, made provision in part for the payment of the expenses of some of the delegates to the Rome 1922 meeting of the International Geodetic and Geophysical Union. During the first year of the existence of The International Geodetic and Geophysical Union, the annual dues for the United States were paid by the National Research Council from special funds received for the payment of annual dues of the established international unions. In the following years, however, the annual dues have been paid by Congressional appropriation in the Diplomatic and Consular bill of the State Department, there being included in this appropriation also the dues for the International Research Council and unions established by it. The Council has also borne the expense of publication of papers and reports by the Union.

V. CHARACTER OF ANNUAL MEETINGS

The character and purpose of our annual meetings has naturally varied from year to year in accordance with circumstances. The meetings of 1920, 1921, were largely concerned, as is the present meeting, with submission and discussion of special reports and papers. The meeting of last year was chiefly devoted to the discussion and preparation of reports relating to the Rome meeting of the International Geodetic and Geophysical Union in May 1922.

Our programs of this year for each of the sections are replete with interest, and while the Committee on Meetings has laudably endeavored to arrange the meetings of the several sections so as to avoid conflicting interests as much as possible, one might, nevertheless, wish that it were possible to have all papers and reports presented at general meetings of the entire Union. There might be held, however, brief sessions of each section for the transaction of strictly business matters and for the presentation of purely technical reports and papers. We may be in danger of losing the chief advantage of our annual gatherings if we do not find it possible to make provision in future for more general sessions to which all papers, or at least the chief ones, would be presented and then afford ample opportunity for discussions, conferences, or symposiums, on mooted questions, not

infrequently of interest and importance to several of the sections, and possibly to all of them.

VI. SECTIONS AND COMMITTEES

Perhaps some consideration may have to be given in the near future as to how best to avoid the dangers arising from possible over-organization and too intense sub-division into groups and committees. One of the chief objects of our Union from the very beginning has been, as already stated, to provide a common meeting-ground, or clearing-house, for our varied aims and researches, with the minimum amount of machinery or organization.

Not all national committees have as yet formed themselves into sections corresponding in general to those of the International Geodetic and Geophysical Union, as Belgium, Canada, France, Japan, Spain, and the United States have done. However, national committees in most countries are composed of less than twenty-five persons, so that splitting up into sections might not be advantageous. The status of the American Geophysical Union, as already explained, is somewhat different from that of other national committees. For, in the first place, in order to have adequate representatives of the greatly varied interests in geophysics over the entire extent of the United States and outlying territories, it has been necessary to have in our Union about three times the average membership of national committees. In the next place, we have endeavored to unite in our Union the objects of both a national committee and a national geophysical society.

It is of interest to note the provisions for geophysics made by progressive Japan. The National Research Council of Japan consists of about 92 members, grouped into the following 9 divisions: General Affairs, Astronomy, Geophysics (10 members), Chemistry, Physics, Geology and Geography, Biology and Agriculture, Medical Sciences, and Engineering. In addition to this Division of Geophysics, which is on equal footing with the other divisions, there is a "National Committee for Geodesy and Geophysics," consisting of the 10 National Research Council members of the Division of Geophysics, and 13 co-opted members, who are not members of the Council. The chairman and vice-chairman of both the Division of Geophysics and of the National Committee are, respectively, Professor A. Tanakadate and Professor K. Nakamura.[1]

In conclusion, permit me to advert to a question raised in our pioneer days, as to whether an organization like ours, composed of so

[1] National Research Council of Japan, Proceedings, No. 1, March, 1922, pp. 16–21.

many different groups and devoted to such a variety of world-embracing subjects, which to some appeared but slightly related, could find sufficient points of interest to avoid disintegration and splitting up into several organizations. But our Union has held together and promises still to hold together.

Department of Terrestrial Magnetism,
Carnegie Institution of Washington,
Washington, D.C.

ORGANIZATION AND AIMS OF THE NATIONAL GEODETIC AND GEOPHYSICAL COMMITTEE OF CANADA[1]

NOEL OGILVIE, *Superintendent, Geodetic Survey of Canada*

Dr. E. Deville, Chairman of the National Committee of Canada of the International Union of Geodesy and Geophysics, received a letter dated April 4, 1923, from Dr. Louis A. Bauer, Chairman of the American Geophysical Union, advising him that arrangements had been made to allow time at this meeting for the presentation of an address on "The Organization and Aims of the National Geodetic and Geophysical Committee of Canada." This honour Dr. Deville has kindly conferred upon me and it gives me great pleasure to be with you and to present this address on behalf of the National Committee of Canada.

The National Committee of Canada, of the International Union of Geodesy and Geophysics, was formed by the Honourary Advisory Council for Scientific and Industrial Research, and I received a letter from Dr. A. S. Macallum, the Administrative Chairman, dated the 23d of April, 1920, reading as follows:

"I have the honour to inform you that you have been appointed a member, ex officio, of the National Committee for Canada of the International Union of Geodesy and Geophysics, the other members of which are as follows:

The Director of the Dominion Observatory, ex officio
The Surveyor-General, ex officio
The Director of the Meteorological Service, ex officio
The Director of the Geological Survey, ex officio
The Superintendent of Tidal and Current Surveys, ex officio
The Chief Hydrographer of the Naval Service, Department, ex officio
Four representatives of The Royal Society of Canada.

"The appointment of the representatives of The Royal Society of Canada will probably be made at the meeting to be held in the third week of May.

"As soon as these representatives are appointed a meeting of the Committee will be called by Dr. Deville, who has been appointed Convener."

At a meeting held on May 20, 1920, the following four representatives of The Royal Society of Canada were appointed and their names added to the list of members of the National Committee of Canada of the International Union of Geodesy and Geophysics:

Professor L. B. Stewart, University of Toronto
The Seismologist, Dominion Observatory
C. A. French, Magnetician, Dominion Observatory
Professor R. W. Brock, University of British Columbia.

[1] Presented at the Annual Meeting of the American Geophysical Union in Washington, April 17, 1923.

Dr. Deville was elected Convener of this Committee and his first duties were the preparation of the By-Laws and Regulations governing the work.

A preliminary and organising meeting of the National Committee of Canada was held at the Geographic Board rooms, Ottawa, on Tuesday, May 25, 1920. Dr. Deville was made Chairman of the National Committee and Mr. C. A. French was made Secretary.

At this meeting Dr. Deville gave a detailed account of the genesis of the International Research Council, the General Assembly of which was held at Brussels during July 1919, and the subsequent formation of the International Union of Geodesy and Geophysics, reading the essential extracts from the constitution and statutes of the Council and of the Union, pointing out especially that the Union was divided into the six following sections: Geodesy, Seismology, Meteorology, Terrestrial Magnetism and Electricity, Physical Oceanography, and Volcanology, and that each of these sections has its own president and secretary, and that each may publish reports, etc.; in short, that each is an entity in itself. It was stated that Canada represented two units in the Union, its population being between five and ten millions, the maximum units being eight for population over twenty millions; and furthermore, that the Research Council had paid the first annual contribution of 5200 francs for Canada to the International Union.

Dr. Klotz amplified the remarks of the Chairman by giving an account of what had been done in the United States in connection with a similar national committee of which he had been supplied with the minutes; in connection with the National Committee there had been formed a permanent American Geophysical Union which, in co-operation with the United States National Research Council, would take part in the International Union.

Before the adjournment of the meeting, Dr. Deville and Dr. Klotz were appointed a committee to draft the necessary Constitution and By-laws for the National Committee of Canada, for subsequent submission to the Committee and then for the approval of the Research Council.

The preliminary draft of the Aims of the National Committee was prepared by the above-mentioned Committee and at a meeting held on May 19, 1921, the Statutes were amended as follows:

STATUTES

The National Committee of Canada constituted by the Advisory Council of Scientific and Industrial Research for the International Union of Geodesy and Geophysics.

ARTICLE 1

Objects

(a) To assist in carrying out the objects of the International Geodetic and Geophysical Union, which are: To promote the study of problems relating to the shape and physics of the earth; to initiate and organise the conduct of researches which depend on co-operation between different countries, and to provide for their scientific discussion and publication; to facilitate particular researches such as the comparison of instruments used in different countries.

(b) To promote and co-ordinate the study of the various branches of geodesy and geophysics in Canada.

(c) To formulate problems encountered in investigational work requiring solution, for presentation through the National Committee to the International Union.

(d) To seek the assistance of others not members of the National Committee in matters pertaining to any of the sections of the Union.

(e) To publish, if found desirable, the activities of the National Committee in order to further research in Canada in the various fields of the Committee of the Union.

ARTICLE 2

Membership

The membership of the National Committee shall consist of the eleven originally provided by the Research Council, and such other active investigators in the above fields who have been proposed to the National Committee, and whose election requires a two-thirds affirmative vote by ballot of the members of the National Committee. Additional members may be elected without calling a meeting of the Committee.

ARTICLE 3

Sections

The National Committee shall be divided into Sections corresponding to those of the International Union, viz: Geodesy, Seismology, Meteorology, Terrestrial Magnetism and Electricity, Physical Oceanography, and Volcanology. Each section may appoint its own Chairman and Secretary.

The members shall designate the Section, or Sections, to which they desire to belong.

ARTICLE 4

Officers

The officers of the National Committee shall be a Chairman and a Secretary to serve until the conclusion of the next General Assembly of the International Union and until their successors have been duly elected.

ARTICLE 5

Appointments

In case of absence of the Chairman at any meeting, the meeting shall appoint a temporary Chairman for such meeting.

ARTICLE 6

Executive Committee

The Executive Committee shall consist of the Chairman and Secretary, and the Chairmen of Sections, if such have been appointed.

The Chairman and Secretary of the National Committee shall be the corresponding officers of the Executive Committee.

ARTICLE 7

Delegates

The National Committee shall nominate a delegate or delegates to the International Union of Geodesy and Geophysics at least six months before the next meeting of the General Assembly.

ARTICLE 8

Amendment

Amendments to the Statutes may be made at a meeting called for that purpose provided notice of such amendment has been sent to the Secretary at least one month before the above meeting.

The question of additional membership and the personnel of the various Sections was taken up at the meeting held on May 10, 1921. It was decided to increase the membership of the National Committee as provided for in Article 2 of the Constitution; also, in order to facilitate the work of the Committee and Sections, to appoint the Chairman and Secretary of each Section. Each new member was elected and assigned to a Section as that particular Section was under consideration, it being assumed that the action of the Committee in assigning the member to the Section would meet with his approval. The members constituting the the different Sections, also the officers, as chosen by the members present, are as follows:

Geodesy

Chairman, Dr. E. Deville, Chairman, National Committee, Ottawa.
Secretary, Noel J. Ogilvie, Superintendent of the Geodetic Survey of Canada, Ottawa.
Professor L. B. Stewart, University of Toronto, Toronto.
W. M. Tobey, Senior Geodetic Engineer, Geodetic Survey of Canada, Ottawa.

Seismology

Chairman, E. A. Hodgson, Seismologist, Dominion Observatory, Ottawa.
Secretary, F. Napier Denison, Meteorological Service, Victoria.
Dr. Otto Klotz, Director, Dominion Observatory, Ottawa.

Meteorology

Chairman, Sir Frederick Stupart, Director, Meteorological Service, Toronto.
Secretary, J. Patterson, Meteorological Service, Toronto.

Terrestrial Magnetism and Electricity

Chairman, Dr. Otto Klotz, Director, Dominion Observatory, Ottawa.
Secretary, C. A. French, Magnetician, Dominion Observatory, Ottawa.
W. J. Stewart, Chief Hydrographer, Department of Marine and Fisheries, Ottawa.
W. E. W. Jackson, Magnetician, Meteorological Service, Toronto.

Physical Oceanography

Chairman, Dr. W. Bell Dawson, Superintendent of Tidal and Current Surveys, Department of Marine and Fisheries, Ottawa.
Secretary, W. J. Stewart, Chief Hydrographer, Department of Marine and Fisheries, Ottawa.

Volcanology

Chairman, Dr. William D. McInnes, Director of Victoria Memorial Museum, Ottawa.
Secretary, Dr. W. H. Collins, Director of the Geological Survey, Ottawa.
Professor R. W. Brock, University of British Columbia.

The membership of the National Committee of Canada of the International Union of Geodesy and Geophysics, including the eleven original members, is at present twenty-one.

The fees for Canada due to the International Union of Geodesy and Geophysics are at present charged to the appropriation of the Geodetic Survey of Canada.

In conclusion I may say that the aims and organization of all the Sections of the National Committee of Canada, namely, Geodesy, Seismology, Meteorology, Terrestrial Magnetism and Electricity, Physical Oceanography and Volcanology, are first to co-operate with other investigators in the British Empire, and to unify and co-ordinate all results with those of the United States and Mexico, so as to build up one complete whole over North America, and secondly, to co-operate as much as possible with the whole of Europe, etc., in the obtaining of uniform results and methods which can be used for scientific purposes.

STATUTES AND BY-LAWS OF THE AMERICAN GEOPHYSICAL UNION

(As amended to May, 1923.)

PREAMBLE

The American Geophysical Union is hereby established by the National Research Council. It supersedes the "American Section of the proposed International Geophysical Union." The American Geophysical Union is the American National Committee of the International Geodetic and Geophysical Union and the Executive Committee of the American Geophysical Union is the Committee on Geophysics of the National Research Council. The American Geophysical Union is constituted as follows:

ARTICLE 1

Objects

(a) To assist in carrying out the objects of the International Geodetic and Geophysical Union, which are: To promote the study of problems concerned with the figure and physics of the Earth; to initiate and co-ordinate researches which depend upon international co-operation, and to provide for their scientific discussion and publication; and to facilitate special researches, such as the comparison of instruments used in different countries.

(b) To promote and co-ordinate the study of the various branches of geodesy and geophysics in the United States of America and its outlying territories.

ARTICLE 2

Membership

The membership of the American Geophysical Union shall be as follows:

(a) Those who composed the membership of the "American Section of the proposed International Geophysical Union" on July 1, 1919.

(b) Those who may be appointed by the Executive Board of the National Research Council upon nominations submitted by the Executive Committee of the American Geophysical Union.

(c) The Chairman of the Division of Foreign Relations, the Chairman of the Division of Physical Sciences, the Chairman of the Division of Chemistry and Chemical Technology, the Chairman of the Division of Geology and Geography, and the Chairman of the Division of Biology and Agriculture, of the National Research Council, members *ex officio*.

(d) The American officers of the International Geodetic and Geophysical Union and of its Sections, members *ex officio*.

ARTICLE 3

Sections

The American Geophysical Union shall be divided into Sections, in accordance with the organisation of the International Geodetic and Geophysical Union, as follows: (a) Geodesy; (b) Seismology; (c) Meteorology; (d) Terrestrial Mag-

netism and Electricity; (e) Oceanography; (f) Volcanology; and, in addition, (g) Geophysical Chemistry.

The members shall designate the Section, or Sections, to which they will belong. The *functions of the Sections*, in their respective fields, shall be the promotion of the objects of the American Geophysical Union.

ARTICLE 4

Officers of the American Geophysical Union

The *Officers of the American Geophysical Union* shall consist of a chairman and a vice-chairman, elected to serve for a period of two years, and not to be eligible for immediate re-election to their respective offices; and a secretary, to serve for a period of three years.

ARTICLE 5

Officers of Sections

The *Officers of the Sections* of the American Geophysical Union shall consist for each Section of a chairman, a vice-chairman, and a secretary, whose periods of office shall correspond to those of the Union. The Chairman of each Section shall have the power to appoint, with the right to vote, a representative of the Section to such meetings of the Executive Committee of the Union as he may be unable to attend.

ARTICLE 6

Executive Committee

The *Executive Committee* shall consist of the chairman, the vice-chairman, and the secretary of the American Geophysical Union, and of one representative from each of the sections of the Union, who shall be the chairman thereof or a member appointed by him; and, in addition, *ex officio*, the chairman of each of the following Divisions of the National Research Council: Foreign Relations, Physical Sciences, Chemistry and Chemical Technology, Geology and Geography, and Biology and Agriculture. Those present shall constitute a quorum. This Committee shall have charge of all administrative matters of the American Geophysical Union, and shall be the representative of the Union in its relations with the National Research Council and with the International Geodetic and Geophysical Union. The Executive Committee, in consultation with the Sections, shall nominate to the Executive Board of the National Research Council delegates, or representatives, to the meetings of the International Geodetic and Geophysical Union and of its Sections, in accordance with the regulations fixed by the International Research Council for the voting power of the United States of America.

ARTICLE 7

Annual Meetings

The American Geophysical Union and its Sections shall meet annually at such time and place as may be chosen by the Executive Committee of the Union. The officers of the Union and of the Sections shall be elected at this annual meeting.

ARTICLE 8

Special Meetings

Special Meetings of the American Geophysical Union, or of its Sections, may be called when necessary by the respective chairmen.

ARTICLE 9

By-Laws

The American Geophysical Union is authorized to enact such by-laws as may be necessary for the performance of its functions and duties.

ARTICLE 10

Amendments

Amendments to the Statutes of the American Geophysical Union shall be subject to the approval of the National Research Council.

BY-LAWS

The fiscal year of the American Geophysical Union shall conform to the fiscal year of the National Research Council.

Standing committees on Statutes and By-Laws, on Membership, on Meetings, and on Budget, shall be appointed for the ensuing fiscal year by the Chairman-elect of the Union prior to the beginning of each year.

All committees of the American Geophysical Union shall terminate at the end of the fiscal year for which they may be appointed.

Meetings of the Union shall be called at least thirty days in advance, and those present at the meeting shall constitute a quorum.

Meetings of the Executive Committee shall be called by the Chairman, and those present shall constitute a quorum.

Final action shall not be taken by the Executive Committee on matters affecting any Section in the absence of the Chairman of such Section, or his representative.

No mail ballot shall be closed until at least thirty days after the date of issue.

After thirty days' notice has been given, amendments to the Statutes (all of which are subject to the approval of the National Research Council) may be voted on either by mail or at a regular meeting of the Union.

Amendments to the By-Laws may be proposed either by mail or at a regular meeting; when voted on by mail they require for adoption a majority vote of the members; when voted on at a regular meeting they require for adoption a three-fourths vote of the members present.

Any amendment to the Statutes or By-Laws proposed by at least five members shall be submitted for vote to the members of the Union by the Executive Committee.

A member of the American Geophysical Union may be dropped from the Union by a three-fourths vote of the members of the Executive Committee.

Statutes and By-Laws adopted by a Section shall not conflict with the provisions of the Statutes and By-Laws of the Union.

Matters pertaining to a Section or Sections, and not pertaining to the Union as a whole, shall be acted upon by the Section or Sections concerned.

REPORT OF MEETING OF THE INTERNATIONAL GEODETIC AND GEOPHYSICAL UNION AND ITS SECTIONS HELD AT ROME, MAY 2-10, 1922, PREPARED BY DELEGATES FROM THE UNITED STATES

GENERAL CONFERENCE OF THE INTERNATIONAL GEODETIC AND GEOPHYSICAL UNION

WILLIAM BOWIE

The first general conference of the International Astronomical Union and of the International Geodetic and Geophysical Union, since their establishment at Brussels in July 1919, was held at Rome, Italy, May 2 to 10, 1922. The meetings of the two Unions and of their various Sections were held in the Reale Accademia dei Lincei. About three hundred delegates and guests, representing about twenty countries, attended the various meetings.

The first day was occupied by the registration of delegates and the opening of the conference, which was held at the Campodoglio, at which were present the King of Italy and other officials. On the second day there were meetings of the two Unions at which various committees were appointed to consider certain questions of administration and policy. On the last day of the conference the Unions also met to receive reports of committees and to conclude the work of the conference. From May 4 to 9, 1922, inclusive, there were held meetings of the several sections of the International Geodetic and Geophysical Union and of the Committees of the Astronomical Union.

The principal matters coming before the Union as a whole were finance and changes in the statutes and organization of the Union. There was complete harmony among the delegates as to the report of the Committee on Finance, dealing with the apportionment among the sections of the quotas of the nations adhering to the Union.

On the question of changing the statutes some decided differences of opinion arose, especially on the question of whether the designation "Section" should be changed to that of "Association" or to some other term. It was the opinion of the American delegates that the term Section does not carry as much authority nor give quite the idea of importance of the several groups of scientists coordinated into the International Geodetic and Geophysical Union. The conference decided that the matter of changing the designation of the Sections should be left to the action of the International Research Council which was to hold a meeting in July 1922.

It was decided, with very little opposition, to recommend to the

International Research Council that the countries adhering to the Reduced Geodetic Association should be allowed to join the Section of Geodesy only, without adhering to the other Sections of the Union. It was also decided that a new Section called Section of Scientific Hydrology, should be added to the Union.

Although there were many advantages in having the two Unions meet at the same time and place it was the feeling of many delegates that the time was entirely too short to accomplish all that was desired by the Sections of the International Geodetic and Geophysical Union and by the various Committees of the International Astronomical Union. Many of the delegates were accredited to both Unions and, necessarily, two or more meetings in which they were interested were frequently held at the same time.

It was decided by the officials of the International Geodetic and Geophysical Union that they would bring before the Union the question of having a meeting in 1924, in order that, thereafter, the three-year interval would bring the meeting of the two Unions in different years. At the close of the meeting of the International Geodetic and Geophysical Union it was decided that the next meeting should be held in 1924 at Madrid, Spain. Representatives of Spain had kindly invited the Union to meet in that city.

As usual, in international scientific conferences social features played a prominent part. The most important of those at the Rome meeting were the inaugural ceremony, at the Campodoglio, mentioned in the early part of this report, the reception at the same place by the municipality of Rome, on the evening of May 4, the visit to the Palatino at the invitation of the Secretary of Antiquities and Fine Arts on the afternoon of May 8 and the visit to the Vatican and the audience with the Pope, on May 10. There were a number of special excursions during and after the meeting, especially one to a number of volcanoes after the close of the conference. At the closing session of the Union appropriate resolutions were adopted, expressing the appreciation of the delegates to those individuals and organizations who by their efforts had made the conference so successful and pleasant.

The following table shows the officers of the International Geodetic and Geophysical Union and of its Sections:

Officers of the Union

President: Ch. Lallemand
Vice Presidents: Presidents of the Sections
Secretary General: H. G. Lyons

Officers of the Sections

Section	President	Vice President	Secretary
Geodesy	W. Bowie	R. Gautier	G. Perrier
Seismology	H. H. Turner	E. Oddone	E. Rothé
Meteorology	Napier Shaw	C. F. Marvin E. Delcambre	F. Eredia
Terrestrial Magnetism and Electricity	C. Chree	L. Palazzo	Louis A. Bauer
Oceanography	Prince of Monaco[1]	J. Parry (Tidal Commission) Odon de Buen (Atlantic Commission) G. W. Littlehales (Pacific Commission)	G. Magrini
Volcanology	A. Lacroix	H. S. Washington	A. Malladra G. Platania
Scientific Hydrology	E. B. H. Wade	A. Wallén	G. Magrini

U. S. Coast and Geodetic Survey, Washington, D. C.

REPORT OF THE SECTION OF GEODESY

WILLIAM BOWIE

As is well known, the geodesists of the world have maintained for a number of years an association called the International Geodetic Association. At its last meeting at Hamburg, Germany, in 1912, the fiftieth anniversary of the Association was celebrated. That Association had held triennial conventions for the purpose of bringing together representative geodesists from the twenty or more adhering countries.

That the International Geodetic Association and its conferences were of great benefit to the science of geodesy is indicated by the fact that practically all of the geodetic work done throughout the world since the organization of the Association has been of such a high standard that it has not had to be duplicated. These beneficial results have been largely due to the personal contact of the geodesists with each other at the triennial conventions and to the efforts of committees and rapporteurs dealing with the various branches of geodesy, and of the officials of the association.

[1] The President died soon after the meeting.

The Section of Geodesy of the International Geodetic and Geophysical Union, which was created at Brussels in 1919, was designed to take the place of the old International Geodetic Association which had been greatly reduced as a result of the war. The old Association had been perpetuated in 1917 by seven neutral countries of which the United States was one; the others were Norway, Sweden, Denmark, Holland, Switzerland and Spain. After the United States entered the war, the Association was composed only of the other six countries mentioned. Too much credit cannot be given to those countries for preventing a break in international co-operation in geodetic affairs during the war. Especial credit is due to the president of the reduced Association, Dr. Raoul Gautier, and the late Dr. H. G. van de Sande Bakhuyzen, the Secretary.

As a result of correspondence of the President and Secretary of the Section of Geodesy with the officials of the reduced Geodetic Association, each one of the countries forming that Association had representation at the Rome meeting in May, 1922.

The Section of Geodesy held almost continuous sessions from the third day of the conference to and including the next to the last day. The first two days and the last day of the conference were devoted to the opening exercises and the meetings of the International Astronomical Union and the International Geodetic and Geophysical Union.

An Agenda had been prepared for the meeting of the Section of Geodesy which, with much explanatory material showing what had been done by the officials of the Section since the organization of the Section at Brussels, was furnished in printed form to the delegates at Rome. The Agenda was very strictly adhered to in the proceedings of the Section, and all that had been projected was accomplished, although there was much crowding of events owing to the limited time available.

At the first session of the Section, a number of committees were appointed, which dealt with questions involving cooperation of geodesists in two or more countries. There was also provided a committee, which should meet with a committee of the International Astronomical Union, to consider the question of the international variation of latitude work. Another committee was appointed to deal with the finances of the Section.

The meetings of the Section of Geodesy were well attended with from 25 to 50 persons present. Committee meetings which, in some cases, had to be held during the sessions, cut down the attendance at various times; besides, some of the geodesists were also representa-

tives of their countries to the International Astronomical Union and to other sections of the Geodetic and Geophysical Union and, necessarily, they were not able to devote all of their time to the Geodetic Section.

The statutes and by-laws of the International Geodetic and Geophysical Union were adopted for the guidance of the Section of Geodesy.

One of the most serious questions which came before the Section was the character of its organization but, after much thought and unselfish effort on the part of a committee appointed on the statutes and organization, a plan was drawn up which was submitted to the Section and adopted without modification. This plan provides that there shall be a president, vice-president and secretary who shall form the Bureau of the Section. These officers together with four others elected by the Section at a general conference will constitute an Executive Committee to carry out the will of the Section, as expressed in its acts at the general conferences, and also to carry out the will of the Permanent Commission.

It was provided that there should be a Permanent Commission of the Section of Geodesy, which should be composed of a single representative of each of the states adhering to the Section. This Commission would have as its principal function to act for the Section on legislative matters which might appear to be necessary during the interval between two general conferences.

The joint committee of the Section of Geodesy and of the International Astronomical Union, on the variation of latitude work, reported that unanimous agreement had been reached, that the latitude work should be conducted by the Section of Geodesy but that there should be a joint committee of the Section of Geodesy and of the Astronomical Union, to consider the various scientific phases of the subject. It was also provided that the Astronomical Union should make contribution towards the reduction, discussion and publication of the results.

The writer of this report made the statement at one of the sessions of the Section of Geodesy that he was authorized to propose that, if the property of the reduced Geodetic Association, at the two variation of latitude stations in the United States, Ukiah, California, and Gaithersburg, Maryland, were transferred to the U. S. Coast and Geodetic Survey, every effort would be made to secure the authority of Congress for the Coast and Geodetic Survey to continue the observations in this country without expense to any international body, provided that the stations in Japan and Italy should be main-

tained without international expense by those two countries. The representatives of Japan and Italy agreed to this proposition provided, of course, their countries would confirm their action. Since the Rome meeting the Director of the U. S. Coast and Geodetic Survey has been in communication with the Secretary of the Section of Geodesy, making efforts to put into effect the plan proposed at Rome.

At the last session of the Section of Geodesy, reports were received from the various committees which had been appointed at the beginning of the conference, and such action was taken on the reports as seemed desirable. It is not necessary to refer to the Committee reports, except in so far as has already been done in the early part of this statement for there will be given a complete report of the proceedings at Rome in the *Comptes-Rendus*, now being prepared by the Secretary.

The Section of Geodesy elected as its vice president Raoul Gautier who since the death of General Bassot of France, in January, 1917, has been president of the reduced Geodetic Association. The four members elected to the Executive Committee are H. J. Heuvelink, G. P. Lenox-Conyngham, Paul Stroobant, N. Vacchelli.

William Bowie of the United States will continue as President of the International Section and G. Perrier of France will continue as Secretary for another term.

It was provided that there should not be any Central Bureau, such as had existed in the old International Geodetic Association. To replace the Central Bureau, provision was made for rapporteurs for the several branches of geodesy. The rapporteur for a subject would have as his duties the collection of information from the geodesists of the world and the furnishing of information and advice to such as might desire it from the officials of the Section, and the making of a report at the general conventions on the status of the subject assigned him and the progress which has been made since the preceding conference.

The following rapporteurs were appointed at the Rome meeting: Bases and Triangulation, G. Perrier; Precise Leveling, Ch. Lallemand; Geodetic Astronomy (latitude, longitude, azimuth), to be designated by Ordnance Survey; Deviation of Vertical, H. DeGraaff Hunter; Intensity of Gravity, E. Soler; Isostasy, W. Bowie; Projections, H. Roussilhe; Earth Tides, H. G. Gale; Stability of the Earth as a Timepiece, E. W. Brown.

U. S. Coast and Geodetic Survey,
Washington, D. C.

REPORT OF THE SECTION OF SEISMOLOGY

HARRY FIELDING REID

The meeting of the Union took place in Rome, May 2-10, 1922, at the headquarters of the Reale Academia dei Lincei.

The Section of Seismology, which was not organized in Brussels in 1919, on account of possible complications with the International Seismological Association, was organized on May 4. Professor H. H. Turner, of Oxford, England, was elected President; Signor Emilio Oddone, of Rome, Italy, Vice-President; and M. Rothe, of Strasbourg, France, Secretary and Director of the Central Bureau, which it was decided to maintain at Strasbourg.

The section is to receive 27,000 francs annually from the Union, a sum far inferior to the income of the former International Seismological Association (about 51,000 marks). Its activities will therefore be much restricted. To continue the cataloguing of important earthquakes recorded by seismographs, 10,000 francs annually were voted to Professor Turner, who will have to supplement this sum (by probably an equal amount) from other sources. The remainder of the income, 17,000 francs, was voted to the expenses of the Central Bureau: they will be used to publish the proceedings of the meetings, to disseminate seismological information by wireless, to carry on the general work of collaboration of the Central Bureau, and, if possible, to publish some memoirs; but the activities of the Section will necessarily be more restricted than were those of the old Association.

Several committees were appointed: (1) to work out a practical system of rapid transmission of seismological information (2) to consider the transmission of earth waves due to explosions (3) to consider a means of expressing the usual scales of earthquake intensities in dynamic units (4) to study the cause of microseisms (5) to study the depths of earthquake foci.

Three seismological papers were read and discussed. M. Somville (Belgium) gave a simplified method of determining the constants of a Galitzin seismograph, Signor Lo Surdo (Italy) explained an easy method of determining experimentally the intensity of earthquake vibrations in dynamical units, and of correlating this intensity with the Rossi-Forel, the Mercalli, or any other similar scale; and Mr. Reid (United States) showed that the friction of seismographs registering mechanically could be taken into account satisfactorily more accurately and more simply than by Galitzin's theory.

An interesting excursion was made by the Section to Rocca di Papa, the principal Italian seismological observatory. A luncheon was

given by the Mayor of the town, and Professor Agammenone, in charge of the observatory, received us most cordially and explained the instruments and the work he is carrying on.

Johns Hopkins University,
Baltimore, Maryland.

REPORT ON THE DISSOLUTION MEETING OF THE INTERNATIONAL SEISMOLOGICAL ASSOCIATION, STRASBOURG, APRIL 24-25, 1922

HARRY FIELDING REID

The delegates met at the Institute de Physique du Globe, Strasbourg, April 24-25, 1922. The following allied nations were represented by delegates: Belgium, Brazil, Canada, France, Great Britain, Japan, Norway, Portugal, Spain, Switzerland, United States.

Dr. Hecker (Germany), former director of the Central Bureau of the Association, and Professor de Kovesligethy (Hungary), former secretary were present. Several other states of Central Europe were represented by proxy.

On account of the death of Prince Galitzin, the president of the Association, and the illness of Professor Lecointe, the vice-president, Sir Arthur Schuster, a former president, was elected to preside.

It was decided that the International Seismological Association came to an end on March 31, 1916, that being the end of the period determined by the original convention. It seems that some States have not paid their quota to that date, whereas others have paid their quota for some succeeding years. It was decided to ask all States in arrears to March 31, 1916, to make up their arrears; and to return to all States which have paid quota beyond that date the sums so paid. If the member States agree to this plan and act accordingly there will remain in the treasury of the Association about 18,400 francs. (It is not certain that all arrears can be collected.) It was decided to pay to the former secretary, Professor de Kovesligethy the sum of 5000 francs for the very considerable work devolving on him in closing up the affairs of the Association, and to use the remainder for printing and distributing the proceedings of the Dissolution Meeting, and in meeting other small expenses incident to the dissolution.

It was decided to transfer to the Seismological Section of the International Geodetic and Geophysical Union, the library and scientific documents, and other properties of the Association. The "other properties" are unimportant.

The decisions of the meeting were adopted unanimously. In order

to make these decisions effective, it is necessary that the member States ratify them. I think them eminently fair and practical, and I strongly hope that our State Department will ratify them. They offer a simple solution of what might have been a difficult matter. Our country has paid its quota to the Association only to March 31, 1915, and therefore according to its undertaking when it joined the Association, and in accordance with the action of the Dissolution Meeting, it still owes one year's quota, April 1, 1915 to March 31, 1916. The amount is 4000 francs, which, at the present rate of exchange is but little over three hundred dollars. Our annual quota before the war was 3200 marks, or about $800.

Johns Hopkins University,
Baltimore, Maryland.

REPORT OF THE SECTION OF METEOROLOGY

HERBERT H. KIMBALL

Meetings were held daily, except Sunday, from May 4 to 9, inclusive, and in addition a joint meeting with Section (D), Terrestrial Magnetism and Electricity, was held on May 5. Sir Napier Shaw of England presided at all the meetings. In the absence of Professor Marvin, the Secretary, Dr. Kimball, the delegate from the United States, was asked to serve as Secretary pro tem; and Professors Platania and Eredia, delegates from Italy, were designated Assistant Secretaries.

In all, thirty-three delegates were in attendance, representing most of the allied nations, and a few that were neutral, during the world war.

The Section particularly concerned itself with two subjects: (1) its relations with the International Meteorological Committee, and the International Conference of Directors of Meteorological and Magnetic Institutions, and (2) plans for international cooperation on certain research problems.

With reference to (1) it was agreed that all questions of a routine or an administrative character should be referred for consideration to the International Meteorological Committee, the Section confining its activities to scientific problems the solution of which calls for international cooperation. Furthermore, the International Conference of Directors of Meteorological and Magnetic Institutions, which is to meet in Holland in 1923, was asked to consider if there is a duplication of work in its functions and those of the Union.

With reference to (2) resolutions were adopted providing for certain researches, the procedure for the carrying out of which will be

outlined later by the Bureau of the Section. These researches include the following:

(1) The determination of the quantities of hydrogen in the atmosphere in different localities and at different heights.

(2) The exploration of the upper atmosphere by means of sounding balloons in regions which are of especial importance from the point of view of the general circulation of the atmosphere, and which have not at the present time an effective meteorological organization for carrying on work of this kind.

(3) The examination of the dust in the atmosphere in different countries.

(4) A report on our knowledge of the radiation from the sun, the soil, the sea, and the air, from the point of view of the general circulation of the atmosphere.

(5) A report from the several countries affiliated with the Union on the methods they employ in weather forecasting.

(6) A study of the details of convection in the atmosphere.

(7) Commendation of the work on solar radiation carried on by the Astronomical Observatory of Naples, and by the Astrophysical Observatory of the Smithsonian Institution of Washington.

The budget of the section was approved as follows:

General expenses	5,000 francs
Exploration of the air by sounding balloons	20,000 francs
Exploration of the stratosphere by pilot balloons	5,000 francs
Examination of the dust of the atmosphere	2,500 francs
Total	32,500 francs
Allotment	32,542 francs

The Bureau of the Section is constituted as follows:

President,	Sir Napier Shaw,	England.
Vice President,	Professor C. F. Marvin,	United States.
Vice President,	Colonel Delcambre,	France.
Secretary,	Professor F. Eredia,	Italy.

The Executive Committee consists of the Bureau, and the following:

Dr. G. C. Simpson,	England.
M. Alex Wallen,	Sweden.
Professor F. Gamba,	Italy.

U. S. Weather Bureau,
Washington, D. C.

REPORT OF THE SECTION OF TERRESTRIAL MAGNETISM AND ELECTRICITY[1]

LOUIS A. BAUER

A well-attended meeting of the Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union was held at Rome from May 4–9, 1922. During the seven sessions, twelve different countries were represented by thirty-three delegates and guests, viz:

J. M. Baldwin, G. F. Dodwell, E. F. Pigot (Australia); J. Jaumotte (Belgium); H. Morize (Brazil); J. Bosler, H. Deslandres, E. Delcambre, E. Mathias, Ch. Maurain (France); C. Chree, A. L. Cortie, W. C. Parkinson, Arthur Schuster, Napier Shaw, G. C. Simpson (Great Britain); A. Alessio, F. Eredia, L. Palazzo, D. Pacini, G. Platania, A. Pochettino, G. B. Rizzo, C. Somigliana (Italy); K. Nakamura (Japan); J. Krassowski (Poland); J. Galbis, L. Rodés (Spain); D. Stenquist, A. Wallen (Sweden); L. A. Bauer, G. W. Littlehales (United States); E. Deville (Canada).

Professor Tanakadate, who was unable to be present at Rome, had requested to be relieved of the presidency of the Section, because of his inability to attend to the duties. The resignation was regretfully accepted and Dr. Charles Chree, who as vice-president had presided at all sessions, was elected, at the closing session on May 9, president, and Professor Luigi Palazzo, vice-president; both of these officers, according to the statutes, serve for two terms. The secretary and director of the Central Bureau, Dr. Louis A. Bauer, continues in office until the next meeting, which will be at Madrid, Spain, about September 1924. Directors J. Jaumotte (Belgium) and Ch. Maurain (France), and Professor A. Tanakadate (Japan), in addition to the three officers of the Section, were constituted the Executive Committee. It was agreed that administrative matters should be left to the Bureau, consisting of the officers of the Section.

Since the meeting at Brussels in July 1919, when the International Section of Terrestrial Magnetism and Electricity was established, nearly three years have elapsed. While the organization of the work of the Section, because of the post-war conditions, could not proceed as rapidly as it was hoped, nevertheless definite progress has been made regarding which the Agenda (Ordre du Jour) for the present

[1] The full report has appeared in a volume published by the International Section and is entitled "Transactions, Section of Terrestrial Magnetism and Electricity, Rome, 1922"; it is designated as "Bulletin No. 3." A general report, published in the September 1922 issue of *Terrestrial Magnetism and Electricity*, was reprinted as "Bulletin No. 2," and a copy was sent to each member of the American Geophysical Union.

meeting were at least one indication.[2] Perhaps for the first time we have had presented in so concrete a form the salient questions, both practical and theoretical, pertaining to the magnetic and electric states of our Earth and its atmosphere. It was not to be expected, nor indeed, was it desirable, that definite decisions on all the questions should be reached at that meeting. However, it must be a source of gratification that by the united action of the National Committees the crucial questions and problems have received a definite formulation.

Reports were presented showing the status of magnetic and electric work in the various countries represented, and containing the opinions of National Committees, leading organizations, and investigators on items of the Agenda. There were, furthermore, reports from committees constituted at the Brussels meetings, as also reports and letters expressing the views of some, whose countries either were not officially represented at Rome (Greece, New Zealand), or did not yet belong to the International Geodetic and Geophysical Union. Among the latter there were letters from E. van Everdingen (Holland); G. Reinius, D. Stenquist, and V. Carlheim-Gyllensköld (Sweden); C. Störmer (Norway); G. Melander (Finland); and C. Ryder (Denmark).

On the basis of all information on hand and the ensuing discussions on items of the Agenda, twenty Resolutions[3] were passed. The Executive Committee was empowered to formulate more definite recommendations on some of the mooted questions of procedure, especially at magnetic observatories, as soon as further information has been received by the secretary from all service and observatories engaged in magnetic or electric work, in response to a questionnaire sent out.

Five committees were appointed:[4] (1) Committee on Magnetic Surveys and International Comparisons of Instruments; (2) Committee on Observational Work in Atmospheric Electricity to report on Objects, Instruments, and Methods; (3) Committee on Measures of Magnetic Characterization of Days; (4) Committee on Best Methods, Instruments and Compilations for Polar Light Observations; and (5) Committee to Consider and Report on Best Methods and Instruments for Earth-Current Observations. The provisional organization of these committees was undertaken. The Executive Committee was

[2] See *Terr. Mag.*, vol. 26, pp. 151–152, 1921 for English text; the French text will be found in the reprinted general report (Bulletin No. 2).

[3] See reprinted general report (Bulletin No. 2), or "Transactions" (Bulletin No. 3, pp. 174–177).

[4] The representatives of the American Geophysical Union on the international committees are: (1) Louis A. Bauer, chairman, and N. H. Heck; (2) W. F. G. Swann; (3) R. L. Faris; (4) J. A. Fleming; (5) S. J. Mauchly, secretary.

empowered to add to the membership of committees, as additional countries join the Union, and to form any additional committees deemed necessary to put into effect the Resolutions. Provision has also been made for consideration of questions concerning the relationships between solar and the Earth's magnetic and electric phenomena in the following manner: (1) A committee on solar radiation, under the chairmanship of Dr. George E. Hale, of which Dr. Bauer is a member, was formed by the International Astronomical Union; (2) The International Research Council at its Brussels meeting in July 1922 has decided to assist in initiating studies of the correlations between solar and terrestrial phenomena, this being a subject of the kind in which several unions would be interested.

The balance, 30,892 francs, of the accumulated funds in hand, arising from the contributions, 1919–1922, of the adhering countries at the rate of 400 francs per contributing unit, was made available to the International Section. This is in addition to the sum of about 1,500 francs which had been supplied in 1921 for incidental expenses. There will, furthermore, be available during the period of 1922–1924, from the contributions of adhering countries, annually an amount at the rate of 320 francs per contributing unit. It is estimated that the annual amount from this source will be about 22,000 francs. Hence the International Section will have available for its various purposes during the period 1922–1924, in all about 75,000 francs,[5] which is subject to increase as additional countries join the International Geodetic and Geophysical Union. With the aid of the funds thus available it is hoped that matters of international concern and benefit may be energetically pursued, as, for example, frequent intercomparisons of magnetic standards, the chief expense of which during the past sixteen years has been borne by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. The Secretary and Prof. E. Mathias, as alternate, were made members of the Finance Committee of the Union.

The Executive Committee was authorized to incur the necessary expense for the publication, in the most suitable form, of the minutes and proceedings of the Rome meeting and of the various reports received, as well as for the issue of any additional publications which may be found desirable and which the available funds may permit. It is estimated that the volume of proceedings will approximate 200 octavo pages, and that it may be distributed in 1923.[5] By means of bulletins, issued from time to time, it is hoped that prompt information may be given regarding matters of international interest, progress

[5] Approximately, according to present rate of exchange, about 4,000 United States dollars.

on mooted questions, action taken and recommendations by the Executive Committee, and other committees of the Section, and National Committees, latest values of the magnetic and electric elements at observatories, and so forth.

Department of Terrestrial Magnetism,
Carnegie Institution of Washington,
Washington, D. C.

REPORT OF THE SECTION OF PHYSICAL OCEANOGRAPHY[1]

G. W. LITTLEHALES

At the first assembly of the Section, which took place on Wednesday, May 3, 1922, confirmation was given to the recommendations of the Executive Committee for the appointment of three commissions to be called, respectively, the Commission of the Atlantic, the Commission of the Pacific, and the Commission of the Mediterranean.

The proposal of the Executive Committee that, in addition to the president or chairman of the Tidal Commission, the presidents or chairmen of these three commissions should be vice-presidents of the Section was adopted.

Your delegate was elected Vice-President of the Section and President of the Commission of the Pacific, and was continued in membership in the Commission of the Atlantic and its sub-commission and also in the Tidal Commission. Steps have been taken to organize the Commission of the Pacific in harmony with the Committee on Pacific Investigations of the Division of Foreign Relations of the American National Research Council.

The Commission of the Mediterranean was continued as constituted in November, 1919.

Indorsement was given to the proposal of Senator Volterra, for the publication in the Bulletin of the Section the *Comptes Rendus* of transactions in physical oceanography throughout the world.

The proposal of Professor Magrini, for the formation of a new section in the International Union of Geodesy and Geophysics to be called the Section of Continental Hydrography was referred to a special committee of which the American delegate to the Section of Physical Oceanography was a member. The proposal was opposed under instructions from the American delegation. This opposition

[1] A detailed report of the proceedings of the International Section of Physical Oceanography at its meeting in Rome May 2–10, 1922, is soon to be published by the Secretary of this Section, in connection with the reports of the other Sections of the International Union of Geodesy and Geophysics and with the report of the proceedings of the Union itself. Accordingly the present statement touches only upon such transactions as are entitled to anticipatory mention.

occasioned the modification of the proposal of Professor Magrini into a new proposal for the creation of a Section of Scientific Hydrology, which was adopted by the Committee of the Union appointed to consider and report upon the original proposal.

The committee appointed to prepare an International Glossary of Nomenclature and Terms used in Hydrography and Oceanography reported an advanced stage of progress.

A new committee was appointed to examine into existing international conventions which might aid researches in physical oceanography.

The International Hydrographic Bureau was brought into connection with the International Section of Physical Oceanography by the election, as a Vice-President of the Section and Chairman of the Tidal Commission, of Sir John Parry, President of the Directing Committee of the International Hydrographic Bureau. This proceeding followed the resignation of Professor Lamb as Vice-President of the Section and Chairman of the Tidal Commission.

The Tidal Commission reported in favor of introducing, into the title-note concerning tides on nautical charts, a table of harmonic constants for the computation of the time of tide instead of the usual statement of the Establishment of the Port or High Water at Full and Change, especially in these regions where declinational tides are predominant.

At the final meeting of the Section on May 10, in connection with the passage of the budget for the ensuing fiscal year, provision was enacted for the annual expenditure of 5,000 francs in each of the ensuing five years for the preparation and printing of the International Manual of Oceanography.

U. S. Hydrographic Office,
Washington, D. C.

REPORT OF THE SECTION OF VOLCANOLOGY

H. S. Washington

I have the honor to report as follows on the meeting of the Section of Volcanology held at Rome, Italy, May 2–10, 1922. It will be pertinent to state that I have not yet received any copy of the minutes of the Proceedings made by the Second Secretary, Prof. Gaetano Platania, of Catania. I understand that he met with a somewhat serious accident, which has evidently delayed him. I must consequently rely on my memory and on some scanty notes made by me. The present report must, therefore, be considered as subject to correction in the future.

The first meeting of the Section of Volcanology was held at the rooms of the Accademia dei Lincei, in the Corsini Palace, at Rome, on May 4. Those present were: Messrs. Lacroix (France); Malladra, Millosevich, Nasini, Novarese, Oddone, Gaetano Platania, and Somigliana (Italy); Iwawate (Japan); and Washington (United States). Prof. Lacroix was elected Chairman of the Section for a term of three years, and Dr. Washington was elected Vice-Chairman for a like period. Dr. Malladra was elected First Secretary to fill out two years more of his term, and Prof. Gaetano Platania was elected Second Secretary. In the absence of Prof. Malladra after the first day, Prof. Platania acted as Secretary during the whole meeting.

A general discussion of the agenda which had been proposed for consideration took place. These agenda were:

1. International co-operation in the sending out of news and information regarding new eruptions.

2. International co-operation on the obtaining of data regarding submarine eruptions and earthquakes, and the examination of ships' log books for records of them.

3. The subject of deep borings at volcanoes. During the discussion of this topic an interesting account of the Larderello Works in the development of power from subterranean heat and steam was given by Prof. Nasini and one of the engineers of the company.

4. International Catalogue of Volcanoes.

5. Study of thermal gradients.

Other matters discussed were: The publication of a Bulletin of Volcanology; what should be understood by the term "active volcano"; an international bibliography of the active volcanoes of each country; the establishment of a central volcanological library. Further consideration of these matters was laid over until the next meeting.

The next and last meeting of the Section took place on May 9, the same persons being present, except Dr. Malladra. Discussion of the topics mentioned above took place; it was finally decided that the formulation of definite proposals and decisions be left to a Committee composed of Messrs. Lacroix, Malladra, and Washington, who were to meet later at Vesuvius. Announcement was made by the chairman that the annual income of the Section would be about 20,000 francs, derived from about 70 units of the International Geodetic and Geophysical Union, each unit being 260 francs. After the usual votes of thanks the meeting then adjourned, until the next meeting to be held in Madrid, Spain, in 1924.

After the meeting an excursion was made to the active volcanoes of Italy by Prof. and Mme. Lacroix, Prof. and Signora Gaetano Platania, Prof. Oddone, Prof. Iwawate, Dr. Washington, and several

others. The trip lasted from May 12 to 22 and included an excursion around Etna by rail and motor car, the ascent of the volcano and the spending of the night at the top. The Aeolian Islands were visited, by the courtesy of the Ministry of Marine, who placed a torpedo boat at our disposal. A night was spent on Lipari, the volcano of Vulcano was visited, and a night circuit gave a splendid view of the activity of Stromboli, and the ruins of Messina were seen. On the return the crater of Vesuvius and the Observatory were visited by several members of the party.

Messrs. Lacroix and Washington met Prof. Malladra at the Observatory of Vesuvius on May 21, and held the Committee meeting; at this meeting Prof. H. F. Reid was also present by invitation. It was agreed that:

1. The Central Bureau of the Section of Volcanology should be at the Vesuvius Observatory, with an office in Naples, to be in charge of Prof. Malladra, as First Secretary; a subsidiary bureau to be at Catania, under the charge of Prof. Gaetano Platania.

2. It was recommended that, if it can be arranged, a Bulletin des Publications Volcanologiques be established, devoted especially to the recording of volcanic eruptions and related occurrences, including hot springs, mofetti, volcanic earthquakes, the petrology and mineralogy of volcanoes, etc. It was understood that by the term "active volcanoes" those in eruption in Quaternary and Recent times be meant.

3. The publication of an International Catalogue of Active Volcanoes was recommended. It was suggested that a committee from the volcanologists of each country should take charge of the cataloging of the volcanoes of its own territory, as well as of the bibliography, as suggested in the next topic. The details of what is to be included in the catalogue were discussed, and it was agreed that each member of the present committee should make some trials as to the best procedure.

4. The publication of a Bibliography of Volcanoes was recommended, a committee from each country to deal with its own volcanoes. To determine the best form, etc., Prof. Malladra undertook to prepare a bibliography of Vesuvius, and the other two members also agreed to undertake bibliographies of some special volcanoes, such as those of Reunion or Pelee by Lacroix, and those of Hawaii by Washington.

5. It was recommended that suggestions be made to the marine authorities of the various countries as to the advisability and scientific value of issuing instructions or requests to naval and merchant marine officers and to cable companies to report on the occurrence of submarine eruptions, volcanic eruptions in little-visited islands and coastal districts, and such phenomena. It was also recommended that attempts

be made to collate the log books of the various national navies and merchant marines for such data, if possible by some official. All such data should be reported to the central bureau at Naples.

6. The international communication of news of volcanic eruptions and the construction of a code for this purpose was discussed, but no definite action was taken.

7. It was recommended that central volcanological libraries be established at the Vesuvius Observatory, at the Geodynamic Observatory at Catania, and at the Volcano Observatory at Kilauea. To these, authors are requested to send copies of all their publications (past, present, and to come).

The meeting then adjourned.

Geophysical Laboratory,
Carnegie Institution of Washington,
Washington, D. C.

STATUS OF PROBLEMS IN GEOPHYSICS

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RECENT PROGRESS IN GEODESY

JOHN F. HAYFORD

Let us consider the present status and scope of geodesy and look at its problems with a view to making the best progress possible in the near future. The recent past to be brought under review should not be limited to a single year, but to a few years. Similarly our attempt to look into the future should not be limited to the one year until we meet here again.

In recent time there has been a continually increasing application of the results of geodetic surveys to the control of other less accurate surveying and to mapping. There has been a steady improvement in instruments and methods in spite of the fact that these were already very highly developed. Geodesy is once more internationally organized. The available store of fundamental data of geodesy is being increased rapidly. In North America the extension of the area over which there is continuous triangulation all reduced to one datum has been, and is now, very rapid. Geodesy is developing many contacts with other fields of science, by discussion and by action. The discussions of isostasy have been given new life by the realization on the part of many men that isostasy brings new tests to their hypotheses in other fields of thought than geodesy and that their observations in other fields shed light upon the probable mechanism of isostatic readjustment.

This summary statement gives a general view. Let us now consider the separate items of the statement with more detail in order that we may see the matters more clearly, though in doing so we lose some of the better perspective of the compact summary.

With each passing year the statistics of routine operations show that the accurately determined elevations, lengths, directions, and positions given by geodetic surveys, are being used more and more extensively for the control of other surveys. This is the practical application of geodesy. Geodetically determined elevations, lengths, directions, and positions are used to a steadily increasing extent in the control of topographic surveys, which culminate in topographic maps. Recently, also, there has been a strong tendency to use geodetic control to an increasing extent for city surveys which culminate in cadastral surveys and in engineering estimates of proposed projects as well as in maps. Extensive practical applications of the results of any science tend greatly to bring a strong financial support to that science which in turn tends to invigorate the abstract, apparently non-practical, part of the science. That has happened in North America in the past few years.

Geodesy is an old well-cultivated field of science. The instruments and methods of geodesy were developed to a very high degree of perfection before the year 1900. Yet in the decade which is just past, there has been a steady improvement in instruments and methods. Much of this improvement has been intended primarily to decrease the cost and to increase the speed of the observations; as, for example, the improvements in signal lights used on triangulation, in the use of invar tapes in base measurement, improvements in the details in precise leveling, and the introduction of apparatus to record wireless time-signals in observations of gravity and in longitude determinations. Such improvements contribute strongly to an ultimate increase in the accuracy of the final conclusions of geodesy. By merely increasing the *number* of deflections of the vertical and of gravity determinations of a given degree of accuracy, the accuracy and reliability of the conclusions reached are much increased. With increase in the amount of precise leveling there goes normally an increase in the number of closed circuits and a decrease in their size, and this in turn leads to a considerable increase in accuracy of the final results even though there is no change in accuracy in the observing on the separate lines of the net. The application of wireless signals to longitude determinations has made it possible to secure determinations of the highest degree of accuracy in regions, such as the greater part of Alaska for example, in which, formerly, one was forced to use the crude methods of transportation of chronometers or even of moon-culminations.

The crying demand that geodesy furnish a reasonably accurate and reliable method and instrument for determining gravity at sea has apparently produced no progress in the past year. This is probably the greatest opportunity now open for an epoch-making step in geodesy.

With the past year, the International Geodetic and Geophysical Union has become a going concern and its Section of Geodesy, which met for the first time in May 1922, focuses the thoughts of at least eighteen countries so effectively as to make it a worthy successor of the old International Geodetic Association. Once more, after a lapse of a decade, geodesy has the incalculable benefits of international co-operation.

The rapid increase in the United States in the fundamental observational data of geodesy, gravity determinations and observed deflections of the vertical, was brought before this same audience one year ago in a brief review of the statement then about to be taken by Dr. William Bowie to the meeting of the International Geodetic and Geophysical Union. Similar recent rapid progress has been made in Canada. My impression is that there are now available in North America new

geodetic data in the form of available gravity determinations and deflections of the vertical equivalent to at least one-half of all of such data as used in the latest comprehensive geodetic discussions. It seems clear that in the near future a new comprehensive discussion would be opportune.

The most important recent development in geodesy has been the great increase in North America of the area over which there is continuous triangulation all reduced to one datum. That area in the "Supplementary investigation in 1909 of the figure of the earth and isostasy" extended, in 1909, to the four corners of the United States. But within the extreme limits mentioned, there were many large continuous blank regions which have since been supplied with triangulation. Since that time the larger of these blank regions have been greatly reduced in size by new triangulation extending through them. The most notable new pieces of triangulation, from this point of view, have been (1) a new arc of triangulation and traverse lines which is, in effect, continuous from the southern Atlantic Coast westward through Texas to a connection with the old triangulation in southern California; (2) a new triangulation in the vicinity of the 104th meridian from Pecos, Texas, to the Canadian border in North Dakota and (3) an oblique triangulation northwestward from Utah to Oregon with a branch southwestward to the vicinity of Mt. Shasta in California. Before 1900 any one of these three would certainly have been heralded to the world by a special publication and individually recognized as a worthy contribution to progress. Now, in the midst of the much more rapid advance of geodetic operations, they have attracted little attention. But of even more importance than this filling in of the gaps in the already occupied area, are extensions of that area of continuous triangulation down to latitude 17° in Mexico by the government of that country, to the northeast into Canada in the provinces of Ontario and Quebec, and the great extension to the northwest through Canada and Alaska which it is expected will become continuous from the United States to Skagway, Alaska, in the present year, 1923. In due time, in the near future, that extension may reasonably be expected to go far to the northward and westward, to the mouth of the Mackenzie River in Canada and far into the main portion of Alaska. To appreciate the great increase in the accuracy of the determination of the figure and size of the earth which is gained by such extensions of continuous triangulation on one datum, one must realize that said accuracy increases much more rapidly than the linear dimensions of the area. I estimate that in those cases in which the extension is both to new latitudes and new longitudes the accuracy varies at least as much as the cube of the linear dimensions of the

area. It appears, therefore, that North America, through the cordial co-operation of the United States, Canada, and Mexico, will certainly, for a whole generation yet to come, have a stronger hold on geodesy, a better determination of the figure and size of the earth, and a better grip on the closely related problems than Europe and its connected continents can hope to have.

On the other hand, in Europe, together with the two continents with which it is connected by land, Africa and Asia, there is the ultimate possibility of a much larger continuous net of triangulation on one datum than can be secured on the western hemisphere. One of the auspicious signs of new progress in geodesy is the fact that at the 1922 meeting of the Section of Geodesy of the International Geodetic and Geophysical Union resolutions were passed which contemplate the development of great areas of triangulation reduced to one geodetic datum, regardless of international boundaries.

In the past decade, geodesy has developed many contacts with other fields of science. The following list of illustrations of the multiplicity and importance of these contacts is intended to make the preceding statement more concrete, though it is not intended to be exhaustive. Bowie, whose field is geodesy, has found himself forced, in recent discussions, to deal largely with geologic and physiographic aspects of the mechanics of isostasy. Barrell, a geologist, wrote the most extensive and vigorous discussion of isostasy which has appeared in the decade. Lawson, a geologist, has contributed to the understanding of the mechanics of motion in the earth's crust, especially in the form of overthrusts. Such an understanding is now evidently equally desirable to geodesy and geology since it has become clear that isostatic readjustment necessarily involves large horizontal transfers of material. Washington has shown that the densities of the rock in various portions of the earth's surface as computed from their chemical constitution are in general accord with their relative densities as inferred from the doctrine of isostasy. Nansen, in his recent book on "The Strandflat and Isostasy," finds in isostasy the solution of a great physiographic problem. The re-triangulation now in progress in California is an application of geodetic methods of thought and of observation to seismology and to studies of slow deformations of the earth's crust whether accompanied by earthquakes or not. The recent measurement of a very long base in California and its transfer to nearby mountain peaks was a loan of geodetic methods and apparatus to a physicist who is bent on a redetermination of the velocity of light. I understand that the loan has resulted in a raising of the attainable limit of accuracy of precise base measurement. All these matters are indicative of much more numerous and more intimate contacts than ever before

between geodesy on the one hand and geology, geophysics, geochemistry, physiography, and seismology on the other hand. The geodesist no longer works in a field surrounded by a high wall; the wall is disappearing. He finds at many points that the limits of his proper field are so indefinite that he cannot be sure whether he is outside or inside. He finds the workers in adjacent fields coming in to work and talk with him and enticing him out to work and talk with them to a far greater extent than in any earlier decade.

The discussions of isostasy have been given new life by these new contacts, by the new keenness of realization of mutual interests in overlapping fields of thought.

Having in mind that experience indicates that to make the maximum progress in a given field of thought it is desirable to keep in good contact with adjacent fields and even make excursions into them, to keep all factors entering into a problem continuously in mind, and that it is also important to conquer the key problems first, I am led to make the following suggestions:

In the near future, possibly without waiting for a new determination of the figure and size of the earth, the accumulated geodetic data of North America, old and new, in the two forms (1) deflections of the vertical and (2) anomalies of gravity, on a uniform geodetic datum in each of the two cases, should be published, together with a comprehensive discussion by the geodesists in such form as will enable those in other fields of thought to continue the discussion to good advantage from their respective points of view. It is taken for granted that the data will be published both without and with corrections for topography and isostatic compensation computed on a uniform basis.

In the geodesist's discussions as published, especial attention should be given to the character and the rapidity of change of the deflections of the vertical, and of gravity anomalies, as one progresses horizontally from station to station. Is the isostatic compensation regional or local? What is the effective depth of isostatic compensation? To what extent does the isostatic readjustment lag behind the addition of loads at the surface by deposition, as in river deltas, or lag behind the subtraction of loads in regions of long continued erosion? To what extent are anomalies in the direction and intensity of gravity attributable to surface geology even though the isostatic compensation may be substantially complete and perfect? It seems to me that the answers to all these questions are contained in the deflections of the vertical and the anomalies of gravity. The answers may be more reliably and accurately obtained the larger the area over which the deflections and anomalies extend on a uniform datum, and the greater the variety of the conditions at the stations. Experience indicates

also that it is especially important to have some groups of stations with a very dense distribution, even in regions where there is believed to be little local disturbance. The road to progress seems to lie in the publication of the new large collection of deflections and anomalies as proposed, and in a keen analysis of the collection.

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STATUS AND NEEDS OF SEISMOLOGY

W. J. Humphreys

STATUS

The present status of seisomology, at least in respect to popular interest and instrumental equipment, reminds one strongly of the proverbial man who locked his stable door after the horse was stolen. Perhaps, too, if the door had no lock at the time of the theft, in his excitement the owner of the horse bought the first lock he could find, then soon tired of the necessary routine of turning the key, and again became neglectful before the next thief came along.

Whenever any region is visited by a severe earthquake, everyone in the disturbed territory who has a dead seismograph under his charge is immediately galvanized into temporarily running it again, while many others in innocent excitement clamor loudly "Oh, for a seismograph, a seismograph," and various inventors come forward with marvelous designs. But all this voluble enthusiasm commonly is of short duration, while those who got their new toys soon find them less interesting and more exacting than they had imagined, and in the end avoid them as the wise man avoids the deadly upas tree.

And so it has come about that there are scores of seismographs all over the world that are of no value whatever—poorly designed, badly installed, and inadequately operated, or, better, perhaps, not operated at all, but just awaiting the time when someone will have the courage to consign them to their proper place—the junk heap.

But the situation is not wholly bad, for there are a few seismological stations at which valuable records are continuously obtained, although, in great measure, their equipments are more or less experimental and radically different, and the data thus secured all but as variously treated.

There has been, and there still is, much wasted effort in seismology; nevertheless all these independent explorations in many directions, these inevitable pioneer efforts, have served, as nothing else could, to make clear what some of the fundamental problems of seismology

are, and how we should go about getting the data essential to their solution.

NEEDS

We know that seismology requires, as do few other sciences, international co-operation, or, at least, agreement among seismologists, the world over, unitedly to attempt the solutions of certain specific problems, and, therefore, to have comparable equipments and to assemble their records in much the same way.

Theory.—But first of all, now that the preliminary stage of this new science is over, we need, to guide us, a searching mathematical analysis of what to expect, as to velocity and period, of each of the several kinds of seismic waves, under this and that reasonable hypothesis in regard to the structure of the earth. We want to know, for instance, the details of the travel of the waves through the sedimentary layer, the granitic layer, and basaltic layer; and the combination effects of these layers on reflections, and on the so-called long-period or surface waves.

To push these problems, as they should be pushed, much beyond the stage to which they have already been advanced would demand exceptional ability in setting up and solving the equations applicable to elastic solids. The extraordinary difficulty of this problem, or, rather, host of problems, would leave us in despair of any marked progress in seismology, but for the fact that therein lies its appeal to the mathematical physicist. He loves the next-to-impossible problems, and here he has them in abundance.

Design of apparatus.—When the elastician has told us what this and that reasonable hypothesis predicts, instruments must then be designed to test these predictions, and to gather data that will enable the theorist to improve his hypothesis. Here, too, much is demanded—rigid mathematical analysis, ingenious designing, and skillful construction; for neglect of any one of the three means failure.

Location of stations.—The next thing to do, if we are to have an adequate study of seismology, is to determine where the instruments are to be located. The difficulties here are only practical, but, for all that, quite real. Certain regional problems of the highest interest to geologists and engineers may indeed present no serious difficulties in this respect. They can be provided for within the territory of a single government, and financed by a single institution or organization. In short, for this class of problems, co-operation and continuity, each essential to success, are easy to obtain. But that other class, the teleseismic problems, requires a distribution of instruments in various countries and, after that, a continuity of operation, and a unity of purpose, difficult to inaugurate, and all but impossible to maintain.

Publication of data.—What particular seismological data shall we publish? Where shall we publish it? When shall we publish it? All these, and more besides, are important and pressing questions that cannot be rightly answered except by international agreement.

In short then, seismology is well established as a science, and blessed with enough difficult, unsolved problems to guarantee it a future full of healthful struggle and exciting interest.

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STATUS, SCOPE, AND PRESENT-DAY PROBLEMS OF METEOROLOGY

C. F. Marvin

Little is to be gained in this brief account of meteorology and its problems by attempting to state with any fullness the status and scope of the science.

The domain of meteorology is the entire atmosphere, and no boundaries of nations, continents, or oceans of any kind delimit its scope or problems.

For more than half a century the great nations of the earth have given meteorology a national status, either by the entire maintenance of national weather services in some form or other, or by subsidies or contributions in support thereof. At the present time, nearly all civilized countries of the world maintain more or less completely organized services.

The Southern Hemisphere and portions of the tropical regions of the globe are but poorly represented by observing stations, not merely because of the small proportion of land to water areas, but because of imperfectly organized services.

The contributions to meteorology from private observatories and special institutions were invaluable in the past, but the place and work of these are now almost completely occupied by the numerous national services.

The essentially international aspect of the science was early recognized, and harmonious co-operation among the nations has been secured through the so-called International Meteorological Congress, which had its origin in a conference held at Leipzig in 1872 and which has continued to function in a highly satisfactory manner up to the present time. Although its regular sessions were interrupted by the war, the organization was reconstituted at a conference held in Paris in 1919 by invitation of the French Government.

This international organization consists of so-called Congresses which

are held at infrequent intervals. Delegates to a Congress include representatives of all the meteorological services and of the principal private observatories of the world. The permanent working body of the organization is the International Meteorological Committee, which at the present time consists of not more than twenty members, each of whom is a director of some national service. The work of the committee is specialized by the organization of so-called Commissions, which are in the nature of sub-committees charged with special fields of work.

At the meeting of the International Committee held in London in September, 1921, there were twelve commissions of which two were newly created in 1921. The names of a few of these will illustrate the nature of the organizations: Terrestrial Magnetism and Atmospheric Electricity; Maritime Meteorology and Storm Warnings; Meteorology and Agriculture, etc., etc.

The International Geophysical and Geodetic Union, through its section on meteorology, is a new and additional agency by which effective international co-operation, so essential to the future progress of meteorology, can be carried forward.

The International Meteorological Congress will hold its next meeting during the second week of September of this year at Utrecht, pursuant to the invitation of the Director of the Meteorological Institute of Holland, Professor Van Everdingen. The relations of the work of the International Meteorological Committee and that of the Section on Meteorology of the International Geodetic and Geophysical Union is an important topic on the agenda of the meeting.

As lack of time prevents a fuller consideration of these highly important matters, I must take up next some problems of meteorology.

PRESENT-DAY PROBLEMS OF METEOROLOGY

All the phenomena of meteorology are naturally confined to conditions in the earth's atmosphere, and man's first observations and problems were encountered in dealing with terrestrial conditions. It was soon known, however, that the heat reaching the earth from the sun was the ultimate cause of all earthly weather and climate.

Problem 1.—The sun and its radiant energy impressed upon the earth is the first great problem of meteorology. How much do we really know, and of how much are we ignorant, concerning solar radiant energy and its geophysical effects?

Conservative meteorologists have hitherto found the effects of solar *thermal* energy either constant in amount or slightly variable as it reaches the earth fully adequate to explain practically all the phenomena involved in atmospheric circulation. On the other hand, a

few fanciful thinkers, little restrained by a grave paucity of both facts and theory, boldly announce that such solar phenomena as sunspots, very minute and as yet scarcely proved fluctuations from day to day in the intensities of thermal radiations of the sun, exercise important controls upon weather phenomena, growth of vegetation, etc. With even slighter basis of observed facts and more fanciful flights of imagination, a few boldly acclaim that climatic changes occur under the control of solar electric and magnetic emanations.

Here is a genuine problem of fundamental importance.

The meteorologists necessarily must depend upon astronomers and solar physicists for the unequivocal facts concerning the sun and its radiant emanations, and upon the magneticians for terrestrial data concerning phenomena in their domain. America may point with much pride to three great institutions which are unsurpassed elsewhere in the whole world and which are steadily supplying the solar and magnetic data needed in this problem. I refer, of course, to the Mt. Wilson Observatory and the Department of Terrestrial Magnetism, both of the Carnegie Institution of Washington, and to the Astrophysical Observatory of the Smithsonian Institution. Systematic observations from these sources as yet cover barely a score of years, about two sunspot periods, a length of time entirely too short upon which to establish obscure and unknown relations and to evaluate effects which are very certainly of small magnitude.

Finally, on the side of the facts in this problem we have what may be a great superabundance of meteorological data, because these began many years before the needed solar observations. On the other hand, meteorological data are bunched into certain geographic localities and are sadly lacking in others.

The solution of this great problem of solar emanations and our weather and climate is a study of statistical analysis and correlation. It is largely an arm chair problem of the analyst, not a laboratory job of experimentation.

The Weather Bureau, through the careful work of its technical staff, is *slowly, surely and sanely* advancing the science of meteorology with reference to this difficult problem of solar emanations and terrestrial weather and climate. *But everything depends upon intelligent interpretation of data and results.* This is a subject which cannot be discussed in the brief time now alloted.

Problem 2.—Passing from the sun and its emanations to our own atmosphere, we choose for our second problem—*The General Circulation of the Atmosphere.*

Meteorologists of the past, and many of the present day, accept without question the standard text-book versions of the primary wind

systems of the globe. Must we not pause to ask ourselves if we are building upon a perfectly sound foundation of theory and fact? The basic theories of atmospheric circulation were first put upon a firm footing by the mathematical productions of Wm. Ferrel. His contributions are the more remarkable because they really preceded, by a decade or more, the general world-wide organization of numerous meteorological stations and the systematic collection of statistical data. Ferrel's equations were checked against the merest fragment of observed facts, but his general theories continue to hold an unquestioned place in meteorological science.

Let me state a few basic assumptions which underlie these theories and let us see if errors are not likely to be introduced. The old canal theory of interchange of warm and cold air between the equator and the poles calls for an over-and-under type of flow which on a stationary earth should take place along meridians. On a rotating globe, however, the northward moving warm currents must be turned to flow eastwardly while the southward moving currents are diverted to a westward course by the influence of the earth's rotation. There have been many doubts expressed as to the reality of this over-and-under type of flow, as a major feature of the general circulation, and both cloud observations and daily weather maps for the Northern Hemisphere at least seem to justify the conviction which many hold that thermal interchanges between the tropics and the poles are effected by flow and counterflow at the same levels as at the earth's surface; rather than the over-and-under interchange of the theory.

Furthermore, Ferrel has assumed that the Northern and the Southern Hemispheres constitute a balanced pair of atmospheres much as if there might be an impermeable wall or plane of separation extending indefinitely outward from the equator. At least, his theory takes no account of the very great annual transfer of air masses back and forth across the equator which we know must take place and is so exemplified in the historic systems of monsoon winds of the Indian Ocean.

The deepest thinkers among meteorologists believe a re-survey of world-wide meteorological conditions is called for to establish a more comprehensive theory of the general circulation of the air that will take better account of the winds of the globe as they actually appear on weather maps from day to day.

The solution of this problem requires (1) the prompt (telegraphic, if possible) collection of daily or twice-daily weather observations and reports sufficient to construct accurate *daily* weather maps for the entire globe or on separate polar hemispheres; (2) the study of such data by the meteorologist, the mathematician and the physicist, with

a view to the *intelligent* interpretation thereof and the formulation of improved laws and equations of motions.

Obviously, this problem is of such magnitude that the collection of the necessary data and the issue of appropriate world weather maps, embracing and depicting not only surface conditions but, in addition, cloud observations at intermediate and high levels, including free air sounding, require international co-operation and co-ordination of effort of the most earnest and cordial character.

For a period of about six months during 1914 the United States Weather Bureau published its daily weather map of the Northern Hemisphere. It has not been practicable to resume this issue, which the war brought to an immediate termination, although the Bureau continues to prepare the manuscript maps which serve a highly useful purpose in its daily forecasts.

It is believed the time is near at hand when proposals for international co-operation may be made that some great nation be entrusted with the duty and responsibility of the issue of a truly world weather map based upon a suitable number of station reports, the total expense thereof to be equably apportioned among those in co-operation. The Weather Bureau contemplates proposals of this character, and the National Research Council, through the International Geophysical Union and Foreign Relations Committee, can undoubtedly be of great assistance in promoting results.

Problem 3.—I will assign to the third place in my list a group of problems all very closely related to Problem 2, but at the same time capable of separate work and effort. Time permits of presenting these only by title, so to speak:

(a) The ultimate cause of origin and sequence of the cyclones and anticyclones of extratropical latitudes.

(b) The expression *Centers of Action* has been current among meteorologists for a score or more of years. Are all in accord as to the physical reality of the thing connoted by the name? Where is the locus and what are the confines of these indefinite entities?

(c) What makes West Indies hurricanes, typhoons, and like tropical cyclones? How little more we know than the destruction wrought by these mysteries of tropical meteorology.

(d) *Ocean Meteorology and Marine Forecasting.* Full and detailed observations over the vast ocean expanses of the globe are almost impossible of attainment, but the near future promises most important extensions in this field of effort. The subject can merely be mentioned here and some discussion of it will be taken up at another time by the Chairman of Section (c) who has recently made some special study of the problem.

Problem 4.—I include within this problem what we have come to call *Agricultural Meteorology*, which deals with the influence of weather on vegetation, particularly its influence upon animal and vegetable food and textile supplies of the nations and the world.

The greatest present obstacle to progress in this most important economic study is the great inaccuracy in data expressing acreage and yield, and no more important step for real progress can be made than that those agencies of the Government and the nations of the world should inaugurate at once plans for procuring really *accurate* figures on acreage and production of the big staple crops of the world.

The meteorologist engaged in the study of weather and crop relations is constantly confronted with the internal evidence of gross inaccuracies and lack of homogeneity in acreage and yield values.

Problem 5.—Meteorology in Aid of Aeronautics has become a new duty and responsibility devolving upon national services of the major nations. The nature and scope of the problem is obvious from the title. Its solution calls for many more observations by means of kites, pilot and sounding balloons than have been available in the past, also, a co-operation between the personnel of meteorology and aeronautics, in order that each may better understand the problems, needs and services of the other.

Problem 6.—Professional forecasting of the weather is a primary duty imposed upon national weather services generally. Without exception, almost no service attempts to make forecasts for long periods in advance, that is, for months, seasons, etc. I do not believe such forecasts are scientifically impossible, but no sound method is yet known by which they can be made with a sufficient measure of success.

The meteorological problem involved in long-range weather predictions is the problem of what are the *laws of the sequence of weather conditions*. This problem embraces, as one of its parts, the very popular question of *weather and climatic periodicities*.

Many claims have been advanced, and about the same number of skepticisms have been entertained, but as a fact very little is really known, either pro or con, and the subject is one needing careful and systematic study. One serious obstacle is the shortness of nearly all records of data. Little can really be done with long-time changes like sunspot periods and others of still greater length. On the other hand, if short periods of days, weeks, months, or a few years in length, actually exist and persist, abundance of data are available for their disclosure. Almost everything depends upon the use of adequate methods.

Problem 7.—Meteorological Education. Many problems in meteorology cannot be considered here for lack of time, but this brief cate-

gory would be incomplete without mentioning the subject of meteorological education in the schools, and especially advanced education in the universities of the nation.

There is pressing need for higher training in dynamical and physical meteorology as a basis for the profession of weather forecasting of the highest type. The public, agriculture, commerce, and the industries are coming more and more to seek, utilize and demand advance information concerning the weather. The Weather Bureau is finding it increasingly difficult to recruit and maintain its staff of professional forecasters adequate for the increasing demands incident to nothing more than the normal growth of the nation. The great universities should make professional meteorology and forecasting a major course in the physical departments of education. The possibilities of future occupation for students in this field may not seem to be attractive under conditions as they now exist, but I am certain that if a reasonable supply of material and talent of this kind were once to become available it would soon find reasonable opportunities of employment.

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STATUS, SCOPE, AND PROBLEMS OF THE SECTION OF TERRESTRIAL MAGNETISM AND ELECTRICITY

W. F. G. Swann

The work of the student of the earth's magnetic and electric phenomena naturally divides itself into two parts, first the study of the main phenomena themselves, and second the study of their causes and of such subsidiary phenomena as are bound up with them. As regards the main phenomena, we have on the magnetic side the study of the magnitude and distribution of the earth's magnetic field over the earth's surface, and its diurnal, annual, and secular variations. On the electrical side, we have the study of the magnitude and distribution of the earth's potential-gradient, of the atmospheric ionization and conductivity, and the diurnal, annual, and secular variations of these quantities. We also have a class of phenomena which are to some extent distinct, since they are associated with abnormal rather than with normal conditions in the atmosphere. I refer to phenomena associated with the thunderstorm and with the electrification of rain.

Imperfect as is our knowledge of the origin of the earth's magnetic and electric fields, however, we know enough about them to know that they are closely bound up with certain less obvious phenomena in such a way as to make the study of the latter a necessary complement to that of the other.

We have reason to believe that the primary agencies concerned in the diurnal variation of terrestrial magnetism are currents induced in the upper atmosphere on account of the tidal motion of the atmosphere across the earth's lines of force. The magnitudes of these currents depend upon the conductivity to be assigned to the upper atmosphere, so that all phenomena likely to be associated with the production of such conductivity come under the natural scope of our study. We believe the aurora to be caused by the entry into our atmosphere of corpuscular rays of some kind from the sun, and to such rays we also look in part for an explanation of the conductivity of the upper atmosphere. We naturally expect, as indeed we find, a close connection between auroral phenomena and those of terrestrial magnetism. The closeness of the relation is increased by the known connection between these phenomena and magnetic storms. Thus, the study of the aurora, and of all matters concerned with it, such as the nature of the radiations responsible for it, the nature and composition of the upper atmosphere in which the luminiscence occurs, the theoretical aspects of the bending of the corpuscular rays by the earth's magnetic field, all these fall within the scope of our interest. The close connection between these phenomena and the sun's activity as exemplified in such matters as sun spots brings the sun itself within the field of our studies. Again, the existence of a state of high conductivity in the upper atmosphere has important consequences in respect of the transmission of wireless waves, so that the study of the transmission of such waves around the earth, and of the fading of signals become of importance to us; and, while speaking of wireless telegraphy, I must not omit to mention the matter of atmospheric strays which are evidence of some kind of electric disturbance, whose elucidation would be of great interest to the student of the earth's electrical behavior.

The study of earth-currents interests us, for two reasons; first in relation to their connection with auroral phenomena, and with the variations of the earth's magnetic field, and second, in so far as they may exist in part independently of these varying phenomena, and may be bound up with the earth's permanent magnetic field.

Any phenomena associated with a departure from the normal state of affairs is likely to form a clue in binding together the different elements of our study, particularly if that phenomenon is likely to have a direct influence on some of the main agencies concerned. The measurement of atmospheric and electric elements during an eclipse of the sun is consequently of considerable importance.

Turning to the purely atmospheric-electric side, our interest extends not only to the fields which I have mentioned, but also to various

matters concerned with more or less pure physics, to the ionization which is known to occur in hermetically sealed vessels, and which may be attributed to a radiation of cosmical origin, or may arise from more local causes. The nature of the ionization produced by high speed corpuscles, and the penetrating power of such corpuscles are of fundamental importance in connection with theories of the earth's charge. The amount and distribution of radio-active material over the earth's surface, and in the atmosphere has an important bearing on the atmospheric conductivity at low altitudes, and the student of atmospheric electricity must draw very largely upon the information of the meteorologist in connection with air currents, and the various other meteorological features which so greatly influence the nature of atmospheric electric phenomena at low altitudes.

Finally, I must emphasize the importance to the cosmical physicist, of a close scrutiny of the facts and principles of pure physics. The situation in this regard is enhanced, moreover, from the fact that in dealing with a body of the earth's size we find that phenomena which would be quite imperceptible in laboratory experiments assume a degree of importance which is at times almost fantastic. Thus, currents started in wire circuits in our laboratories and left to themselves will not die out immediately. The inertia of the electric current will insure that they persist for a short time, but for a time so short that, in general, delicate means are necessary to register it at all. Currents started in a copper sphere of the earth's size, and left to themselves will take 10 million years to decay to one-third of their initial values as Lamb has shown. A current density of the order one hundred millionth of an ampere does not produce very startling effects in most laboratory experiments, but, a current density of this order in the body of the earth will give rise to a magnetic field equal to the whole of the earth's magnetic field. So the story goes, and he who would seek the origins of the earth's magnetic and electric phenomena must be prepared to peer into all sorts of possibilities and even to concern himself with the structure of matter and the problems which lie in the domain of the pure physicist. Moreover, in doing this, he must adopt a view point which is in some cases more fine grained than that of the pure physicist, for he must be prepared to seize upon the most minute possibilities in existing theory, and upon possibilities of modifying existing theories to extents which, while negligible for the purpose of the pure physicist may be for him the solution of some great problem of cosmical scale. A student of the subject must possess a rapid intuition, and a keen sense for orders of magnitude that he may see quickly what is likely to be important and what trivial. He must possess mathematical power to enable him to trace the consequences

of the facts to their logical conclusions; but frequently, a mathematical problem chosen *ad hoc* leads to difficulties which no man can surmount, so he must possess a certain subtlety of vision, which will enable him to avoid the more difficult paths to his goal, and cause him to formulate his problems in such a way that while they lead to the information desired, they are possible of solution. Finally, he must possess a sound knowledge of the principles of physics, and above all of their logical connection with each other. He must not merely know the laws, but he must understand the structure; for, he will have to tamper with structure. He may have to remove a prop here and there, or modify the scaffolding occasionally, and woe betide him who tampers with a structure with which he is not familiar. He will assuredly produce many results, but alas for some of their consequences.

It seems that the time has come when the student of terrestrial magnetism will have to familiarize himself more and more with that great revolution in our ways of thinking exemplified in Einstein's General Theory of Relativity. Already we hear that Einstein has been successful in including terrestrial magnetism in his general scheme. Every student of the subject has felt that this step must come sooner or later; for, so fundamental is the change which the theory of relativity makes, not, of course, in the facts, but in our way of describing them, that to develop a theory of relativity for gravitation and leave terrestrial magnetism out would be to talk in two different languages in two different branches of physics. It may always be convenient for most practical purposes to speak in terms of magnetic fields and the like, just as it will always remain convenient for most purposes to speak in terms of the Newtonian theory of gravitation; but it is important that one who interests himself in the fundamentals of the subject, and seeks what he may choose to call the causes of the phenomena which he studies shall be fully conversant with those modern developments in thought in which the ideas of cause and effect exhibit themselves in such altered form.

I now turn to suggestions for problems which it would seem worth while to attack. First let me refer to a few pertaining more particularly to atmospheric electricity.

The earth's charge is leaving it at such a rate that 90 per cent of it would be gone in ten minutes were there no means of replenishing the loss, and there is a very important class of theory which attributes the replenishment to high speed corpuscles shot into the earth either from outside of our atmosphere or from the atmosphere itself. There are two great difficulties in such assumptions. The first arises from failure to detect any charging effect due to the absorption of these

corpuscles by an insulated mass of metal, and the second arises from the fact that since, as far as our laboratory experiments go, a corpuscle moving with a velocity comparable with that of light should produce 40 pairs of ions in each centimeter of its path, and since the replenishment of the earth's charge requires the influx of 1,500 corpuscles per square centimeter per second, we should expect these to produce about 40,000 pairs of ions per c.c. instead of only about one ten thousandth of this amount as experiment shows to be the case. I have recently tried to remove the second of these difficulties by showing that corpuscles with velocities sufficiently near to the velocity of light should fail to ionize, but the first difficulty remains; and, while it is not unsurmountable in the case of certain types of corpuscular theory, it would be a great comfort if we could measure such a charging effect. I sought such an effect eight years ago, and more recently the effect has been sought independently by Von Schweidler, but in both cases without success. On the other hand, in view of the fact that auroral phenomena, which are attributable to corpuscular radiations from the sun, are concentrated so sharply in certain zones of the earth's surface, it would seem of the greatest importance that a search for this charging effect should be sought in those zones.

The second problem I have to suggest has to do with certain consequences which should result from the existence or non-existence of the supposed region of high conductivity in the upper atmosphere. I can illustrate the matter in this way. Suppose that there is no such condition as this layer and suppose that we have rain falling from a cloud to the earth, the rain being as it usually is, positively charged. The positive charge will not spread itself uniformly over the earth, because it will be held bound in the immediate vicinity of the cloud. In other words, the effect of a rain storm on the potential gradient would be practically local. Now, if there is a conducting layer in the upper atmosphere, the situation is changed. In this case the cloud sets up a difference of electrical potential between the layer and the earth, which is handed round more or less uniformly to all parts of the earth. On submitting this matter to calculation I find, for example, that if h is the height of the cloud and H, the height of the layer, the positive charge to be found on that half of the earth which is remote from the cloud is h/H of what it would have been if the charge had been uniformly distributed, and R/H of what it would have been if the layer had been absent, R being the radius of the earth. The upshot of all this is that, if there is no conducting layer, practically all of the charge should remain on the part of the earth to which it falls, after due allowance is made for conduction back to the atmosphere on account of the conductivity of the atmos-

phere, whereas, if a layer is present, an appreciable part of the charge should be transferred to other regions of the earth. If then, at a number of stations in a region where it is raining, we measure the charge actually brought down by the rain, and the rate of accumulation of charge density on the ground after correction for the current back to the atmosphere, we have a means of testing whether or not the charge remains where it falls, and consequently of deducing certain information with regard to the presence or absence of a conducting layer. A practical method of making the test would be the following: Suppose we have a large insulated tray at the ground level, and exposed, of course, to the potential gradient. Allow the rain to fall into this tray after connecting it to earth and then insulating it. Keep the potential constant and zero by feeding electricity into it from a condenser in a manner of which the details will be sufficiently obvious to need no description. It will be obvious that in cases where the rain is sufficiently steady and prolonged to permit of a steady state being attained, measurements of this kind, at any rate when made simultaneously at a number of different places, will lead to information as to the rate at which charge is passing from the regions immediately below the cloud to those more remote.

Another avenue of attack on the conductivity of the upper atmosphere is to be found through the medium of wireless waves. If the transition from practical non-conductivity to high conductivity is sufficiently sharp, marked reflection of electro-magnetic waves should result; and, by suitable arrangements, the details of which I must not enter into, it should be possible to measure the time taken for wireless waves to travel to the layer and return, and so deduce the altitude of the layer.

The great importance attaching to measurements of the atmospheric elements at high altitudes, and particularly of the residual ionization in gases is so self-evident that it is hardly necessary to do more than refer to it in passing.

The problem of the conductivity of the air over the great oceans is by no means satisfactorily settled. The conductivity is far greater than can be attributed to the radio-active materials in the ocean itself, or in the air over it. It has been customary to invoke, for the explanation of the ionization over the ocean, a penetrating radiation of cosmical origin whose assistance has also been invoked to account for the ionization which is known to occur in a hermetically sealed vessel free from radio-active materials, and suitably shielded from such radiation of ordinary gamma-ray type as may come from radio-active materials in the surroundings. Unfortunately, recent experiments have thrown considerable doubt upon the reality of this pene-

trating radiation, at least as to its existence at low altitudes; and, it may be that, in order to account for the residual ionization in vessels and for the conductivity of the ocean's air, we shall have to resort to the assumption of a spontaneous ionization of the gas itself. A full understanding of the origin of conductivity in the lower atmosphere thus renders it imperative that we strive to solve this question of the origin of ionization in closed vessels (or more important still, the origin of the ionization which would occur in the air in the absence of the vessel) in order that we may know whether it is really necessary to invoke an external radiation, or whether the causes of the ionization are inherent in the gas itself.

I now turn to a few matters having a bearing upon the earth's magnetism. If, as seems likely, the earth's magnetism is bound up with its rotation, a knowledge of the magnetic fields of other heavenly bodies, and attempts to detect the magnetic fields of rotating bodies of laboratory size become of importance, since such information gives us a clue to the way in which the magnetic field varies with dimensions, angular velocity, density, etc. Thus to illustrate the point in question, suppose we were to seek an explanation of the earth's field on the basis that, on account of the centrifugal force of the earth's rotation, the free electrons in its interior must suffer radial displacement, with a resulting production of a magnetic field on account of the rotation of the electro-static distribution thus brought about. As a matter of fact, the field in this case can be calculated, and amounts to only 10^{-23} of the earth's field, but suppose that there had been some element in the calculation which prevented our obtaining the actual magnitude, and gave us only the form of the expression for the field. The field on the equator at the surface in this case comes out proportional to $\omega^3 a^2$ where ω is the angular velocity and a the radius of the sphere. It would thus result that on such a theory, a sphere of radius 10 centimeters rotating at a speed of 100 revolutions per second in the laboratory would have a field over a hundred thousand times that of the earth, while the sun should have a field only half that of the earth. Our knowledge of the absence of fields of the above order of magnitude in the case of bodies rotating in the laboratory is therefore sufficient to rule such a theory out of court, and the fact that the sun has a magnetic field of about 50 gauss is additional evidence in the same direction. A large class of theories give the magnetic field proportional to $\omega a^2 D$ where D is the density of the substance. On such theories, the existence of a field of the order 0.5 gauss at the earth's pole would correspond to the existence of a field of the order, 50 gauss at the corresponding place on the sun, a result well in harmony with Dr. Hale's conclusions as to

the magnitude of the sun's field. On the other hand, this class of theory would give quite inappreciable fields for bodies of laboratory dimensions rotating with attainable angular velocities. Such a type of theory would, moreover, lead to the conclusion that we should have but little hope of detecting magnetic fields in the stars other than the dwarfs, for, expressed in terms of mass m rather than density, the expression makes the field proportional to $\omega\, m/a$, so that for given mass and angular velocity, the field is small in proportion as the radius is large. Even the giant stars have for the most part, masses only comparable with that of our sun, so that, on the basis of such a type of theory as that under discussion, the large radii would cut down the surface magnetic fields to very small values.

I now turn to a suggestion which is rather speculative as to its possibilities, but which is perhaps of sufficient interest to warrant mentioning. The question of the permeability of the earth's interior is one which has interested students of the subject, particularly in relation to the possible effects of combined pressure and temperature conditions to be found within the earth. It would therefore not be without interest to make a direct measurement of the average permeability of the earth. The possibilities in this connection are perhaps not as visionary as might be thought at first sight. Suppose we have two cables parallel to each other around the earth's equator, and start a current in one of them. We shall get an induced current, and a definite time integral of current in the other. The magnitude of the latter will depend upon the dimensions of the circuits, the value of the primary current, the resistance of the secondary circuit, and the average permeability of the earth, and will vary by a factor of the order of magnitude of 3 according as the average permeability is comparable with unity, or large compared therewith. Now a simple calculation will show that by starting a current of one ampere, in the primary cable, the order of magnitude of the induced flow in a secondary cable, of resistance say 10000 ohms will be 0.017 coulomb, a very large quantity when considered in relation to what is measurable with a sensitive galvanometer. It will be obvious that the ideal condition stipulated above is not necessary for the purpose of obtaining measurements from which conclusions could be drawn. It is not necessary for the circuits to be immediately adjacent, or to be drawn around the equator, or to be parallel to each other. In fact, a little consideration will show that all that is necessary is that the dimensions of the circuits shall be comparable with the depths to which we wish to extend our information as to the permeability, and their distance apart must not be greater than is comparable with their dimensions. The practical question involved is of course

how far it would be possible to utilize existing cables for such a project as this.

It may perhaps be worth while to call attention to the possibilities inherent in the use of a large coil for automatically recording the instantaneous rate of change of the earth's field at any place, as distinct from what is usually measured, the actual value of the field. The matter may be illustrated by the following example: The diurnal variation of the earth's horizontal intensity is of the order of magnitude of 10^{-8} C.G.S. unit per second. A square coil with sides 100 meters long, wound with 10 turns of wire would give, on the above account, an e.m.f. of 10 electro-magnetic units, or 10^{-7} volt. If the coil were wound with wire of gauge 10, it would have a resistance of 12 ohms, and would therefore cause a current of 0.5×10^{-8} ampere in a galvanometer of resistance 8 ohms. A properly designed galvanometer would give a deflection of about 2 mm. for this current at a scale distance of 2 meters. Of course 2 mm. is not a large deflection, but greater deflections could be obtained by the use of a larger coil, or a coil with larger number of turns of the same kind of wire, in conjunction with a suitably chosen galvanometer, and the above calculation will serve to indicate the possibilities in this connection.

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STATUS, SCOPE, AND PROBLEMS OF THE SECTION OF OCEANOGRAPHY

G. W. Littlehales

As an emissary from the Section of Oceanography, by designation of its Executive Committee, I am to make the summary statement of the scope and problems in relation to the science whose field is the oceanic expanse, covering an area which exceeds, by more than 80 million square miles, the total land surface of the globe and occupying basins whose cubical content is estimated to be fourteen-fold greater than the bulk of all the lands in the world above sea level. The indications are that throughout nine-tenths of its extent, the depths are greater than one mile; throughout two-thirds of its extent, the depths are greater than two miles; and throughout 10,000,000 square miles of its expanse the depths exceed three miles. Many high mountains rise from the foundations of the oceanic basins, sometimes culminating in emergence above the surface of the waters; and many deep depressions sink below the general level of the bottom.

In the Philippine Deep, a sounding of 5,352 fathoms near the Island of Mindanao marks the greatest depression hitherto discovered

in the earth's crust—a depression so profound that if the highest elevation in the world above sea level were set down within the trough, the summit would yet be 3,000 feet beneath the surface of the sea.

Oceanography is defined as comprehending "the investigations which deal with the form and divisions of all the marine areas on the surface of the globe, the winds that blow over the surface waters, the contour of the ocean bed from the sea-level down to the greatest depths, the temperature, the circulation, the physical and chemical properties of sea-water, the currents, tides, waves, the composition and distribution of marine deposits, the nature and distribution of marine organisms at the surface, in the intermediate waters, and on the floor of the ocean, as well as the modifications brought about in living things by the conditions of their existence, the relations of man to the ocean in the development of commerce, fisheries, navigation, hydrography, and marine meteorology. All this vast assemblage of knowledge, which embraces some aspects of astronomy, geography, geology, physics, chemistry, and the biological sciences, makes up the modern science of Oceanography."

It is worthy of note by geophysicists that the accepted gauge and shape of the earth's crust have been derived altogether from continental arcs without measurements over the 71% of the globe's extent occupied by the ocean.

In the foundation upon which the future superstructure of oceanography is to be raised there must be the configuration of the basins, which are the containers of the oceans; and in the other branches of geophysics, as well as in oceanography, the mapping of the two-thirds of earth's surface which is covered with water is doubtless of an importance second only to the importance of mapping the one-third which is comprised in the land areas.

May it be pardoned as an instance of the frailty of human nature if I seem to incline too far to a belief in the saying that "coming events cast their shadows before them," when I point to the recent survey made in 38 days by two vessels of the Navy of a tract of 34,000 square miles of the bottom of the Pacific Ocean, bordering the State of California from San Francisco to San Diego, as an evidence giving grounds for hope in the feasibility of accomplishing the mapping of the oceanic basins by proceeding along the avenues of cooperation among nations that have been opened in the International Union of Geodesy and Geophysics of the International Research Council.

The position occupied by water in the economy of Nature is most remarkable. Everywhere natural conditions are influenced and molded

by its wonderful properties, and yet it is nowhere told how much water there is in the world. But we do know that the presence in the oceanic basins of 324,000,000 cubic miles of this substance having the highest known capacity for heat—which may be gauged by the statement that the specific heat of sea water is about thirty times that of mercury—must constitute the ocean a dominant factor in terrestrial physics, exercising a governing influence through its circulation upon heat transference and upon climate and the development of vegetation, and, by the enginery of its variations in physical and chemical condition from season to season and year to year, promising, when it comes to be understood, to enhance all those wealth-producing sources which operate in seasonal cycles.

I have elsewhere given a summary, in the publications of the American Geophysical Union, showing the means by which, from the unfathomed state of the middle of the nineteenth century, knowledge of the physical conditions in the depths of the oceans has advanced to an approximate conception of the conditions which prevail throughout the various ocean depths—conditions of movement, of temperature, of pressure, of the penetration of light, of gas content, of salinity, of life. Only a general idea of the contours of the ocean bed has been attained, and only a general idea of the bottom deposits covering that bed.

Although there is as yet little ground upon which to base general conclusions, the diversification found to characterize those tracts about which most has been learned appears to support the view that the ocean basins are extensively featured with orographical formations culminating at various depths below the surface of the ocean.

In every stage of the investigation beneath the surface of the ocean, invention has been the resource leading to progress. Our knowledge of the conditions in deep water, and all that takes place beneath the surface, must continue to be dependent on the correct working of instruments, the action of which is, for the time, hidden from sight. The sparse and disconnected observations of the physical elements obtained by means of indicating instruments, unstandardized among themselves, have advanced oceanography in the exploratory stage, but will not fully serve the ultimate purpose of investigating the ocean from the standpoint of thermodynamics. For this purpose continuous records are required, and, hence, the important problems of the present time include the production and perfection of instruments adapted for making continuous records, both at stations and in transit, of such physical properties of the sea as temperature and salinity, in vertical as well as in horizontal distribution. Oceanographers have already commenced to obey the modern tendency in physical research to

replace indicating instruments by recording instruments. The later advances in the science of the tides are ascribable to the continuous recording tide-gauge.

It is by this course that the shadowy evidences of significant oscillatory, pulsatory, and vortical movements in the depths, which have been encountered in oceanographical research, can best be examined and extended for the fulfillment of the purpose of making known their origin and nature. The Japanese have shown the presence in their seas of standing waves, like those known to exist in lakes. Variations in physical condition have also been observed which are most naturally explained by the progression through the body of the ocean of great undulatory movements, like the waves which physicists observe on the boundary surface between media of different densities. The solution of the problem here presented is looked upon as one of the greatest importance both from the standpoint of dynamic oceanography and of biological oceanography. And of equal importance to the oceanographer of the future is to learn what takes place when wind blows over water, and hence the relation between wind and current. The currents of the ocean seem to be subject to a sort of pulsation of which little is known as yet.

Of great significance is the appeal of oceanography for international co-operation seen on all sides in the recognition by oceanographers of the fundamentally world-wide and hence continental and intercontinental nature of the phenomena, and the national and international character of the scientific and economic results to be developed, and the necessity for the application of resources that come only at the call of nations co-operating together. In every department of science the annals of knowledge supply abundant evidence of the importance of method. In recognition of this, it was with unanimous approval that the International Section of Oceanography, meeting in Rome in May, 1922, made provision for the preparation and publication of an International Manual of Oceanography.

U. S. Hydrographic Office,
Washington, D. C.

THE YEAR'S PROGRESS IN VOLCANOLOGY

ARTHUR L. DAY

The progress of volcanology suffered in two important respects as a result of the War. The German undertaking, under the leadership of Branca of the Berlin Academy, which in many respects was the most comprehensive plan for volcano study ever seriously contemplated, was dropped. A second plan, almost equally imposing, was started just before the War by Friedlaender at Naples. A beautiful

laboratory overlooking the city and within sight of Vesuvius was constructed and a journal, the *Zeitschrift für Vulkanologie*, now in its ninth year, was started. This splendid laboratory was taken over by the Italian Government during the War, and, although its return has been promised, its resources have been so considerably impaired that it will be some years before a full return to the pre-war plan is possible. The *Zeitschrift* was continued by Friedlaender from Switzerland by the issue of occasional numbers, but here also a considerable time must elapse before its pre-war status is fully re-established. It is altogether likely that Friedlaender's recent visit to the volcanoes of Mexico and Hawaii will give new impetus to the activities both of the laboratory and its journal.

In compensation for this diminution of activity in Europe the establishment of systematic studies of volcanism in the Dutch East Indies promises to be most fruitful. Founded in 1917 by the Dutch Colonial Government, the records of this work already fill four volumes (*Vulkanologische Mededeelingen*, published in the Dutch language in 1921 and 1922) containing not only records of a wide variety of volcanic outbreaks, but also of sand flows and hot springs. Indeed the record of the eruptions which have occurred in Java and Sumatra during the last few years appears to be very complete.

The administration of this undertaking has taken the form of a commission modeled after the Imperial Earthquake Investigation Commission of Japan, and if appropriate support is provided will offer a continued service to the Meteorological Service.

In this country the most active work is at present being done by Professor Jaggar's Hawaiian laboratory, now under the direction of the U. S. Weather Bureau, and by the Geophysical Laboratory of the Carnegie Institution of Washington. Both of these institutions have been interested since 1912 in establishing upon a stable basis the study of the physical and chemical forces underlying volcanic activity, and both have issued a considerable number of publications in this field, some reasonably complete and some still tentative, and both have in hand more or less definite plans for future development. In particular Professor Jaggar has brought together the necessary funds for a number of borings in the vicinity of Kilauea crater and has already discovered an altogether unexpected temperature gradient both immediately adjacent to the lava basin and in the older deposits known locally as the Sulphur Banks. In the three borings so far made, one of which has reached a depth of nearly 100 feet, no temperature above the boiling point of water corresponding to that elevation has been found. In the case of the boring near the active lava basin this must

have the effect of revising considerably our notions of the dissipation of heat through thermal conductivity.

On the chemical side the borings have served once more to emphasize the participation of water in all of the relations there prevailing, but have not thus far yielded any new data.

The Geophysical Laboratory has completed its survey of the outbreak at Lassen Peak from 1914 to 1917 and has announced what appears to be a plausible explanation of the volcanic phenomena there, which differ considerably from those studied elsewhere in that the temperatures have been found to be very low in view of the violence of the outbreak. This new hypothesis may be expected to have the effect of stimulating further observation of volcanoes of the explosive type in order to determine whether the hypothesis is to find general application or will merely serve to explain an unusual local condition.

A somewhat more elaborate study of the various types of thermal springs associated with volcanism has also resulted from these studies at Lassen Peak. The latter study of hot springs has not been published and the hypothesis in explanation of the mechanism of the activity is thus far only tentatively announced.

The Geophysical Laboratory was also privileged to join with the National Geographic Society in a study of the Katmai eruption of 1912 and the remarkable sand deposit and fumaroles of the Valley of Ten Thousand Smokes. These have been studied both from the geological and the chemical viewpoint, and a number of facts established which appear to be novel in the science of volcanology. So great an extent and intensity of fumarolic activity has perhaps never been witnessed before and the character of the hot sand flow covering several square miles is in many respects unique. Some of the results of these studies have already been published by the National Geographic Society.

Regarding the recommendation made by the Section last year that effort be exerted to secure a complete record of all volcanic outbreaks, it may be of interest to the Section to know that Professor Karl Sapper of Würzburg is continuing his chronological record, and that he now has in preparation a book upon this and other recent work.

On the whole, therefore, although it is not possible to announce a full return of pre-war interest in the study of volcanism, this field of activity has certainly not been lost sight of, and further intensive studies may soon be expected from Japan, from Italy, from the Dutch East Indies, and from the United States.

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STATUS AND PROBLEMS OF GEOPHYSICAL CHEMISTRY

ROBERT B. SOSMAN

The subject-matter of geophysical chemistry was defined three years ago, upon the organization of this Section, as "the physical properties and chemical reactions of the substances and aggregates that make up the Earth." The Section thus occupies the position of a kind of physico-chemical technical adviser to the other Sections of the Union. The members of Section (g) like to feel that their work is fundamental and necessary to the work of all the other Sections. They feel that if research on the physics and chemistry of Earth materials were abandoned entirely, the result would be that while progress in the other branches would by no means cease, it would be progress only of the kind that is easily foreseen, the kind of progress for which an Appropriations Committee can make detailed and specific appropriations covering several years ahead; this is desirable, but we must also strive for the kind of progress which stands out in the history of science when viewed from a distance of fifty or a hundred years, the kind which starts unexpectedly and goes in unforeseen directions. Such advances are dependent upon the development of new methods and instruments and the discovery of new facts in physics and chemistry.

In the organization report just referred to, the subject-matter was roughly classified into two principal groups: (a) Materials at the Earth's surface, and (b) Materials in the Earth's interior. Each was further subdivided into (1) Individual chemical substances, such as calcium carbonate; (2) Aggregates, such as granite; and (3) Larger units of matter, such as glaciers. There is not time for an exhaustive review of the progress of knowledge in these different branches, and I shall, therefore, simply mention various items that come to mind as illustrating the present status of research in fundamental geophysics and geochemistry, as seen by the laboratory investigator.

Individual Substances.—The Geophysical Laboratory of the Carnegie Institution is still the only endowed laboratory devoting the major part of its attention to research in this field. Important papers marking progress in our knowledge of the silicates have been published since 1920, and include papers on the system SiO_2:MgO:CaO, the augites, the melilites, potash feldspar, and the silicates of barium and strontium.

University laboratories in this country in which similar work is being done include Princeton (silicates), Oberlin (colloidal silica and other oxides), Illinois, Stanford, and Rice Institute (colloidal oxides).

Mention should also be made of valuable data on silica and other important oxides contributed by the research laboratories of manufacturing companies, such as the Harbison-Walker Refractories Company.

Governmental institutions have also contributed. For example, we have from the National Museum the continuation of important data on meteorites and the chemical properties of various minerals; and from the Bureau of Chemistry of the Department of Agriculture, work on the constitution of silicates.

The standard reference books for information on the individual chemical substances of the Earth's surface remain, as for some years past, Clarke's *Data of Geochemistry*, Hintze's *Mineralogie*, Dana's *Mineralogy*, and Doelter's *Mineralchemie*. There is a pressing need for a general work on lines more nearly related to the present current of advance in physical chemistry than those named.

Foreign Work.—Some work on the Earth-forming oxides, begun in Norway a few years ago, seems to have been abandoned for want of funds, while to balance this loss a new laboratory is under construction in Sweden, in which it is planned to do research on silicates. The impoverishment of central Europe has greatly diminished the contributions from that quarter, an important source of supply now being industrial laboratories, which in the nature of the case can publish only what is not highly valuable to the industry supporting the work. A geochemical journal, the *Chemie der Erde*, seems to have perished with the completion of volume 1 in 1920, and the *Silikat-Zeitschrift* has not been heard from since volume 2, 1914. On the other hand, *Tschermak's Mineralogische und Petrographische Mitteilungen* has been revived, after a lapse of five years, with the aid of Austrian, American, and Swedish funds.

Plans were made a few years ago for a laboratory in England similar to the Geophysical Laboratory in Washington; it is to be hoped that these plans will be put into execution soon. Some good work has been done in England on silica, principally for its industrial application. In Japan, work on the Earth-forming oxides is being done in several university laboratories, and several new periodicals, including the *Japanese Journal of Astronomy and Geophysics*, are making available, in English, papers which might otherwise remain inaccessible to most of us because of their original publication only in the Japanese language.

Aggregates.—That branch of geophysical-chemical work which I have classified as work "on the properties and reactions of aggregates" has made progress in the continuation of contributions from the Geophysical Laboratory and the Geological Survey on the composition of the igneous rocks and of the Earth's "crust" as a whole; also papers on the principles governing the differentiation of an igneous magma by crystallization under the active influence of gravity, and the development of pressure in a volcanic magma as a result of crystallization.

On the movements of magmas there is an important theoretical contribution showing how gravitational energy may be converted into heat energy within a magma by the process of extrusion from a region of higher to a region of lower pressure.

Compared with the work on igneous rocks and magmas, comparatively little geochemical or geophysical work has been done on metamorphic or sedimentary rocks. Work has been done in some of the directions suggested by Dr. Vaughan in his report on "Research on marine sediments" at the 1922 meeting of this Union, but it is rather to be classed as geological research—the study of natural processes not under experimental control.

The Larger Units.—In the group of researches on the larger units of the Earth and on the Earth as a whole there should be mentioned such contributions as those from the Coast and Geodetic Survey on the Earth's field of force, from the University of Chicago on the mathematics of isostasy, and similar strictly geophysical contributions which are, however, of such particular interest to the Section of Geodesy or other Sections that this passing mention is sufficient.

Among researches bearing on problems of the Earth's interior should be mentioned the recently published data from the Geophysical Laboratory on the compressibilities of minerals and rocks over a wide range of pressures. These data confirm and greatly extend the work of Adams and Coker, and make possible some important deductions regarding the Earth's rigidity, and its properties with respect to earthquake waves.

Future of the Section.—I have referred at the beginning of this report to the possible usefulness of this Section as a technical consultant to the other Sections of the Union. In turn the members of this Section also have interests of their own, closely allied to physics, chemistry, and geology, in which interests they can receive valuable aid by consultation with the geodesists, seismologists, and the other groups in the Union. The most useful activity of the Section at this annual meeting would seem to be, therefore, to meet jointly with one of the other Sections to discuss problems of common interest.

Such a meeting has been arranged this year with the Section of Volcanology, and the subject chosen is "The temperatures of hot springs and the sources of their heat and water supply." The formation of hot springs has often, but not always, accompanied visible or historically recent volcanic activity. On the other hand, hot springs persist in regions where the volcanic activity is of very ancient date, and even in regions where no connection with any igneous rocks can be proved by geologic evidence alone. What is the source of the heat under these varied circumstances, and—a matter of equal interest—

where does the water come from? Speaking broadly, the physicists and chemists have evidence which inclines them to believe that most of the water has come down fairly recently in the form of rain. The geologists and volcanologists, on the other hand, impressed by the evidence of the large part played by water in the formation of igneous rocks, are speculating as to where that water has gone in the past, and incline to the belief that many hot springs represent water which is now being released by crystallizing magmas.

By such meetings as the one just mentioned we may hope to eliminate those differences of opinion which are due mainly to the possession of different kinds of information by the different groups.

This plan raises the question, however, whether a separate organization of Section (g) is necessary or desirable. At the meeting of the International Union there seemed to be no interest in the formation of any corresponding international Section, the opinion being that the subject-matter is so much more closely allied to physics, chemistry, and geology that any diversion of interest is to be avoided. This is a question of organization and administration which may be best referred to the Executive Committee of the Union.

Geophysical Laboratory,
Carnegie Institution of Washington,
Washington, D. C.

RESOLUTIONS

RESOLUTIONS ON SCIENTIFIC QUESTIONS ADOPTED BY THE AMERICAN GEOPHYSICAL UNION, APRIL 19, 1923

(a) That the National Research Council be requested to do whatever may seem practicable to it towards inducing authors of scientific papers to give postal addresses.

(b) Whereas, The United States statutes at large, Vol. 37, p. 913, provide that

> "Hereafter the Executive shall not extend or accept any invitation to participate in any international congress, conference or like event, without first having specific authority of law to do so;" and

Whereas, Since other provisions of law make it impossible for officers of the government to attend and participate in an official capacity in any international foreign congress, convention, meeting or gathering, thus greatly embarassing the scientific departments of the government in conducting the important duties and responsibilities devolving on them, and since the principal object of such congresses, conventions, meetings, or gatherings is to secure between nations the most effective and profitable co-operation in scientific matters; therefore be it

Resolved, That the American Geophysical Union recommend to the National Research Council that appropriate action be taken to present to the Congress of the United States the disadvantages resulting from the effects of the laws referred to above with the object of securing the necessary legislation permitting the Executive and the heads of the various departments to designate duly accredited representatives to attend international foreign scientific congresses, conventions, meetings or gatherings. This legislation should apply especially to meetings of the International Research Council and its branches, and the International Meteorological Committee and like organizations.

(c) That the National Research Council be requested to consider, if found desirable, the question of the publication of seismological data; what data to publish, where to publish, when to publish, and the form of publication.

(d) That the National Research Council be requested to secure if possible a mathematical discussion of the transmission of seismic waves through the earth, and associated phenomena.

(e) That the National Research Council be requested to secure a study of the transmission of artificially produced seismic waves.

(f) Whereas, progress in meteorology and day-to-day weather forecasting demands a map as complete as possible embracing the entire

northern hemisphere or even the entire globe, as far as this may be feasible, and whereas, Such an undertaking requires complete and effective co-operation between all the nations of the globe conducting systematic meteorological observations; therefore, be it

Resolved, That the American Geophysical Union endorses the project of securing a daily weather map of the northern hemisphere, based on telegraphic and radio reports of observations, to the forthcoming International Meteorological Conference to be held at Utrecht, Holland, in September, 1923, and further recommends that such action be taken as may lead to such international co-operation as will result in some one government undertaking the collection of the necessary observational reports and the preparation and publication of a daily map of the northern hemisphere and the distribution of the same to the participating governments.

With the inauguration of this work the circulation of the atmosphere, and other phenomena, as exhibited on a series of maps of this kind could be submitted to the students of the world for the advancement of the science of meteorology and improvement of the forecasting of the weather. It is suggested that the expense of such an undertaking, as far as this relates to the actual compilation and publication of the map itself, should be met either by the sale of the maps or by definite contributions from the co-operating nations.

(g) Whereas, Two resolutions reading as follows were adopted by the Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union at its meeting at Rome in 1922:

> "That national committees be requested to designate, if possible, one observatory in their respective countries for international intercomparisons of magnetic instruments, and to secure intercomparisons of magnetic instruments within their own countries at least once within the course of three years.
>
> "That it is desirable there should be in every country at least one observatory making systematic atmospheric electric observations (especially of potential gradient, earth-air currents, conductivity, and number of ions), which are intercomparable amongst themselves and comparable with similar observations made in other countries;" therefore be it

Resolved, That the American Geophysical Union designate the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey and the Standardizing Magnetic Observatory of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, working in conjunction, as the observatories in the United

States to function in accordance with the first of the two Rome resolutions quoted above; and be it further

Resolved, That the American Geophysical Union endorses the second Rome resolution mentioned above and recommends the early establishment of such an observatory, without at present designating a particular observatory in order not to tie the hands of any organization which may find it possible to carry on the work specified in the resolution in question.

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SECTION OF GEODESY

ON THE ACCURACY OF TIME DETERMINATIONS

R. H. Morgan

Recent intercomparisons of wireless time signals show variations of 0ˢ.2 to 0ˢ.3 in the time from one observatory as compared with that from others, and suggestions have been made that such variations may be due to the astronomical observations, and that longitude work may be subject to similar uncertainties. This paper gives the results of several different investigations into the differences in clock corrections as determined from observations on the different instruments at the U. S. Naval Observatory, on over a thousand nights in the last twenty years.

From these comparisons it was found that the clock corrections determined from definitive reductions of simultaneous observations on two standard instruments rarely differ as much as 0ˢ.1, and that the average difference is 0ˢ.03. The probable error of a clock correction is 0ˢ.014. The large instruments hold together within 0ˢ.03 for a number of years at a time.

It was also found that the systematic or irregular variations of 0ˢ.1 or 0ˢ.2 which occur in time signals are more or less due to the provisional nature of the observations and reductions used, and that by properly planning the provisional work such variations in the preliminary times may be partly eliminated and partly corrected for by later definitive reductions; and that longitude determinations need not be subject to uncertainties of this size.

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THE ACCURACY OF LONGITUDE DETERMINATIONS BY THE U. S. COAST AND GEODETIC SURVEY BY WIRE SIGNALS AND GENERAL FERRIÉ'S PROPOSED RADIO LONGITUDE NET

William Bowie

Almost from the beginning of telegraphy the U. S. Coast and Geodetic Survey determined differences of longitude by telegraph, and a network of lines between longitude stations has been spread over this country. An analysis of this work is opportune, as determinations of differences in longitude by wire signals will soon be superseded by work in which radio signals are used. It is important that the determinations by radio shall not be less accurate than the old work.

In 1897 an adjustment of the longitude net was made in which 63

differences of longitude were used. The average correction to a difference was 0ˢ.019. There were 36 corrections less than 0ˢ.02 and only two greater than 0ˢ.04. Since 1897 new determinations have been fitted into the adjusted net.

Since 1897, there have been determined 98 differences of longitude forming all or parts of 18 closed loops. Of these, 57 received corrections of 0ˢ.01 or less, while only 9 differences had corrections greater than 0ˢ.02. No correction was as great as 0ˢ.03.

During 1922, seven differences of longitude by radio signals were determined. Preliminary results indicate the same accuracy as that obtained in wire longitude determinations.

Gen. Ferrié of the Bureau of Longitudes, Paris, has a comprehensive plan to determine the longitude of fundamental stations around the world by means of radio signals. His plan has received much attention from astronomers and geodesists. Undoubtedly the work contemplated by Gen. Ferrié's plan will be done in the not distant future, but there is some doubt as to the advisibility of incurring the expense that would be involved in having many stations occupied simultaneously, as is proposed by Gen. Ferrié.

His plan is practicable, in so far as accuracy is concerned, provided that methods are adopted which will eliminate systematic errors in the time observations, and provided that the radio signals are received automatically, and that corrections are applied for the reaction time of the various pieces of apparatus used in sending and receiving the signals.

The use of radio greatly enlarges the areas within which accurate longitude determinations can be made.

U. S. Coast and Geodetic Survey,
Washington, D. C.

THE ERRORS WHICH MAY BE EXPECTED IN RADIO LONGITUDE DETERMINATIONS CAUSED BY THE AUTOMATIC SENDING AND RECEIVING APPARATUS

E. A. Eckhardt

It seems to be generally agreed that the time observations as now made by astronomical methods do not yield values which may be relied upon beyond the nearest 0ˢ.01. This fixes the magnitude of the time errors which is admissible in radio transmitting and receiving apparatus when they are used for time-signal work in longitude determinations.

It is those parts of the apparatus which involve mechanical and electrical inertias, which are most likely to lead to lags and possible errors. Telephone diaphragms, relay armatures and relay coils are examples.

Electro-mechanical relays are used considerably, both in signal-sending and signal-receiving apparatus. The magnitude of the lags and their constancy are considerably affected by the manner in which the relays are used. Obviously that adjustment and arrangement which provides the quickest current changes in both the controlling and controlled circuit and the quickest motion of the armature will result in a minimum of lag. Relay users, however, frequently do not follow the practice that this would suggest. A method of studying relay performance, with special reference to magnitude and constancy of lags, was outlined and some typical results were presented and analyzed.

The problem of using relays in receiving radio signals was discussed. Constancy of lag can not be obtained if the relay operating current changes with signal strength. The nature of this difficulty was discussed in some detail and its avoidance by using a radio receiving circuit which is itself of the relay type was considered. The field-service apparatus now in use by the U. S. Coast and Geodetic Survey for radio time-signal recording is of this type. Its lag errors are within the limits required to make it available for use in exact longitude determinations. Where the astronomical observations are made at a field station instead of a fixed observatory, the field-service design of this apparatus makes it especially available for this purpose.

Bureau of Standards,
Washington, D. C.

THE PLACE OF GEODESY IN THE WORK OF THE COMMITTEE ON SEISMOLOGY OF THE CARNEGIE INSTITUTION

ARTHUR L. DAY

An outline was given of the work that has been undertaken by the U. S. Coast and Geodetic Survey in the form of precise triangulation to show whether the earth's crust in California is stable or is in movement and, if the latter, the rate and the extent of the movement. The triangulation which has already been done and that which is under way during the present year will, in the near future, be supplemented by precise leveling which will show the degree of stability of the earth's surface in the vertical direction.

It is only by geodetic work of the most precise character that movements of the earth's surface can be detected between seismic disturbances. With the repetition from time to time of the triangulation and leveling in selected areas it will be possible to make a very careful study of surface conditions and movements. With such information available the seismologist will be able to apply quantitative methods which will greatly advance the science.

Geophysical Laboratory,
Carnegie Institution of Washington,
Washington, D. C.

THE RESULTS OF THE TRIANGULATION DONE IN CALIFORNIA IN 1922 TO TEST THE STABILITY OF THE EARTH'S SURFACE

O. S. Adams

The redetermination of the positions of triangulation stations made in 1906-07, in the California earthquake region, was based upon the stations at Mt. Diablo, and Mocho, situated some fifty miles east of the San Andreas fault line. Since there was some question whether these points might not have moved with respect to each other, the third determination, also by precise triangulation, of the points in 1922 was made to depend upon Mt. Lola and Round Top, located some 160 or more miles east of the fault line.

The mean of the triangle closures was 0".76 and the maximum closure was 1".93. Of the 37 closed triangles, 28 had closures of one second or less. These results show that this triangulation is somewhat better than the usual requirement for precise work. There were thirty-five condition equations in the adjustment with a resulting probable error of an observed direction of ±0".32.

The difference between the 1922 positions and those of 1906 show a displacement of a little less than four feet in a general southward direction. This is less than one part in 200,000 of the distance from Mt. Lola to Round Top, and in azimuth it represents about one second of twist. A southward displacement would require a combination of length and azimuth discrepancy. The lengths of triangulation, in general, can be depended upon to about one part in 100,000; in a scheme tied together as this is, one second in twist should hardly be expected. However, if the old determination of Mt. Diablo and Mocho should have been affected by an azimuth displacement northward and these 1922 determinations by one southward, the azimuth twist could be less even than a half second which might well be expected.

	Displacement 1922–1906 Based on Mt. Lola and Round Top		Displacement 1922–1906 Mt. Diablo and Mocho held fixed	
	Lat. ft.	Long. ft.	Lat. ft.	Long. ft.
Mt. Diablo	−3.4	−0.8	....	....
Mocho	−3.5	−2.0	....	....
Ross Mt.	−3.7	+2.8	−0.2	+4.2
Mt. Tamalpais	−3.6	+0.6	−0.1	+2.0
Sierra Morena	−3.5	−0.5	0.0	+0.9
Loma Prieta	−2.0	−2.9	+1.5	−1.5
Lick Observatory, small dome	−3.7	−2.2	−0.2	−0.8
Farrallon L. H.	−4.9	+0.6	−1.4	+2.0
Point Reyes L. H.	−4.6	+0.4	−1.1	+1.8

The minus sign indicates movement to the south and to the east in latitude and longitude, respectively.

U. S. Coast and Geodetic Survey,
Washington, D. C.

MEASUREMENT OF DISTANCE BETWEEN MOUNT WILSON AND SAN ANTONIO PEAK MADE IN CONNECTION WITH THE DETERMINATION OF THE VELOCITY OF LIGHT BY PROFESSOR A. A. MICHELSON

C. V. Hodgson

The work was undertaken in response to a request by Dr. A. A. Michelson that the Coast and Geodetic Survey determine the length of the line, over 20 miles in length, between Mount Wilson and San Antonio Mountain, with an accuracy represented by an actual error of not to exceed 1/250,000. To obtain the length of this line, which extended over very rugged country, it was necessary to measure a base in the valley lying to the south, and to carry the base length by triangulation to the line desired.

Before beginning the field work, the members of the Division of Geodesy of the Survey examined critically the modern methods of base measurement and triangulation. In the triangulation the choice of figure, the probable error of a direction, and the method of determining the differences of elevations of the stations were examined with special care. The figure selected gives the greatest possible strength in the connection between the base and the Michelson line. Field

methods were adopted which would insure a probable error of a direction of not more than about 0".2 of arc, or about half that obtained in ordinary precise triangulation, and would give the differences of elevation with an error of not more than one foot.

The investigations concerning base measurement were directed principally toward the problem of standards, the accurate measurement of the tension applied to the tape, the probable errors allowable in the grade and alignment corrections, and the general problem of adopting methods of measurement which would minimize the effect of unavoidable small systematic errors.

The location of the base and of the Michelson line made it very difficult to secure the requisite accuracy. The valley in which the base was located was under a high state of cultivation and the base changed in direction so frequently that 19 angle stations were necessary on the base line alone. Moreover, while observing from the base stations to the mountain stations the atmospheric conditions were very unfavorable, as they always are when observing from a valley toward mountains. The field reports, however, indicated a maximum triangle closure of only about 0".7 and an average closure of 0".4 of arc, and it therefore seems probable that the length of the Michelson line will be determined with the desired accuracy.

U. S. Coast and Geodetic Survey,
Washington, D. C.

THE DENSITIES OF DEEP-SEATED MATERIAL OF THE EARTH'S CRUST, AS DETERMINED BY CHEMICAL ANALYSIS, AND THE BEARING OF SUCH DENSITIES ON THE THEORY OF ISOSTASY

HENRY S. WASHINGTON

A résumé was given of the work which had been done by the author, showing that the densities of igneous rocks found at different places on the earth's surface, as computed from chemical analyses, bear a very definite relation to the elevation of the ground at which the rocks are found. The higher the elevation of the earth's surface the less is the density of the igneous rocks. This fact fits in well with the theory of isostasy which postulates that under each topographic feature there is a compensating deficiency or excess in density. The investigations in rock densities and isostasy will give information in regard to the earth's crust that apparently cannot be gained by other means.

Geophysical Laboratory,
Carnegie Institution of Washington,
Washington, D. C.

FORCES TENDING TO CAUSE MOVEMENTS IN THE EARTH'S CRUST

W. D. LAMBERT

The title is extremely comprehensive. Of all the numerous manifestations of force in the earth's crust two have been selected for their bearing on the Taylor-Wegener hypothesis of continental migration: (1) a small force tending to move continents towards the equator; (2) a possible way in which the earth's axis of rotation might be displaced in the body of the earth.

Wegener's form of the hypothesis assumes that the continents may be likened to blocks of lighter matter (called "sial") floating on a magmatic substratum (called "sima"). To move these continental blocks there is needed a *selective* force, one which acts on the continents, not as on mere undifferentiated portions of the crust, but which has on the continents an effect different from that which it has on the surrounding magma. There is such a force tending toward the equator and roughly proportional to the height of the continent above the sustaining magma. It is, however, very minute (of the order of 1/1,000,000 of gravity), and is probably ineffective in moving the continental blocks against the resistance of the "sima."

Large displacements in the position of the earth's axis of rotation in the body of the earth play an important part in Wegener's scheme, although they are not a necessary part of a theory of continental migration. Wegener's explanation of these displacements of the axis or pole (taken from a memoir by Schiaparelli) is mechanically unsound. There is, however, a possibility, not considered by Wegener, of explaining fairly large polar displacements.

Since the earth's rotation is being slowed down by tidal friction, the earth in the past had presumably a greater ellipticity and its free period in the variation of latitude (now 14 months) was more nearly one year, which is the period of forced annual oscillation of the pole due to meteorological causes. This near coincidence of periods would produce resonance and the amplitude of the oscillations in latitude would be greatly increased, perhaps so greatly that the earth's crust would be ruptured under the resultant stresses, thereby producing something the same effect as if the earth were fluid, so that a new mean position of the pole might be established. Our equations for the variation of latitude are limited to small oscillations, so that we cannot follow the changes with mathematical rigor.

U. S. Coast and Geodetic Survey,
Washington, D.C.

SOME PHASES OF THE RESISTANCE OF THE EARTH'S MATERIAL TO CHANGES

C. E. Van Orstrand[1]

The rocks in the crust of the earth are constantly undergoing readjustment as a result of metamorphism, thermal changes, and redistribution of load. Apart from the evidence afforded by shore lines and regions of seismic activity, there is perhaps no well-authenticated evidence of surface movements now in progress. Artificial movements are oftentimes developed in the rocks beneath stone quarries as a result of diminishing the vertical cross section over which the stresses are distributed. It is found in this way that the rocks in certain areas are in a state of ease—practically no strain—while in other areas the stresses approach the elastic limit.

Contrasted with these small displacements are the enormous displacements which have occurred in geological time, some of which are undoubtedly vertical, while in others, the overthrust faults, it appears that large masses have been displaced horizontally over distances of several miles. The Serpent Mound Structure in Adams County, Ohio, and the Bearpaw Mountains, Montana, which are being studied respectively by Professor Walter H. Bucher of the University of Cincinnati, and Mr. Frank Reeves of the United States Geological Survey, are excellent examples of vertical displacement due apparently to gravitational forces. The Lewis overthrust, Montana, is a conspicuous example of horizontal displacement extending over a length of more than 100 miles. Mr. M. R. Campbell, of the United States Geological Survey, estimates the displacement at the southern end of the fault to be about 15 miles. A complete solution of the problem of overthrust faults is perhaps impossible, but it is not improbable that the displacements, following the lines of least resistance, are vertical in the lower portion of the isostatic column, but at or near the top of the column they may be inclined to the vertical, and in extreme cases, may even be horizontal.

The kind of equilibrium acquired by rock masses may be suggested by the after-effect curves of steel tapes. With small loads the curves approach an asymptote parallel to the axis of time, while with larger loads, but not necessarily exceeding the elastic limit, the asymptotes are inclined to the axis of time and there is no approach to a definite state of equilibrium.

Jeffreys' recent evaluation of the thermal contraction of the globe tends to show that cooling alone is more than sufficient to account for the contraction necessary to produce the mountain ranges of the

[1] Published with the permission of the Acting Director, U. S. Geological Survey.

continents. An obvious difficulty encountered in the thermal-contraction hypothesis of mountain building is the concentration of practically all of the thermal contraction of the globe in the small areas occupied by the mountain ranges. It is perhaps not unreasonable, therefore, to assume that the chief forces involved in mountain building are gravitational and therefore vertical—while the strains resulting from thermal contraction are released from time to time and play a minor part only in the development of a mountain range.

U. S. Geological Survey,
Washington, D. C.

SOME RECENT PROGRESS IN ISOSTATIC INVESTIGATIONS

WILLIAM BOWIE

The principal progress made in the theory of isostasy during the past year or two has been the recognition given the subject by scientific organizations dealing with the earth.

At the meeting of the Geological Society of America, held at Amherst in December, 1921, there was a symposium on isostasy at which were presented nine papers which dealt with relations between the theory of isostasy and geological phenomena.

At the meeting of the same Society at Ann Arbor in December, 1922, there were presented several papers in which the theory of isostasy was given consideration.

A valuable addition to isostatic literature is "The Strandflat and Isostasy" by Dr. Fridtjof Nansen, which appeared in December, 1922. The author shows that the isostatic balance was maintained almost, if not perfectly, in Norway during the loading and unloading of the area by ice caps and their disappearance, respectively. He uses the physiographic evidence to show that areas studied by him are in very close isostatic equilibrium.

Possibly the greatest progress made in the theory of isostasy during recent times has been the establishment of the fact that gravity anomalies are, to a great extent, due to the effect of local deviations from normal densities in the material of the earth's crust close to the gravity stations. In the United States there are a number of cases where stations very close together have decided differences in their anomalies. These anomalies could not show such a deviation if their cause were a lack of isostatic balance of the portion of the isostatic shell below them, for if the cause were deep-seated the effect on two stations close together would be very nearly the same. It has been shown that gravity stations on the Cenozoic formation have a decided tendency to be negative in sign, and the largest negative

anomalies in the United States are on that formation. It has also been found that the gravity stations on the pre-Cambrian formation have a tendency to be positive in sign, and the largest positive anomalies in the United States are at stations on that formation.

As a result of showing that the large gravity anomalies are due to the local rather than to regional causes, we are safe in concluding that the earth's crust is more nearly in a state of equilibrium than had been supposed previously.

U. S. Coast and Geodetic Survey,
Washington, D. C.

SECTION OF SEISMOLOGY

INFORMAL COMMUNICATION OF THE SEISMOLOGICAL WORK OF THE U. S. COAST AND GEODETIC SURVEY

N. H. Heck

The proposed transfer of seismological investigation from the Weather Bureau to the Coast and Geodetic Survey, which was recommended to Congress by the Secretaries of Agriculture and Commerce, was discussed—the reason for the proposed action being given. The opportunity was taken to indicate to the Section of Seismology what this action might result in if approved. It was stated that the various seismologists throughout the country are interested in such a change. The definite program outlined included the following:

1. Establish a first-class seismological station at the Magnetic Observatory at Tucson, Arizona, without an increase of personnel at the present. The value of such a station near but not in the California earthquake region was pointed out.

2. Further development would include a similar program at Sitka, Alaska and Porto Rico. At Honolulu a new building and an instrument for measuring the vertical component would meet the needs.

3. Discussion of the further possibilities for the Continental United States was deferred.

It was pointed out that if this program resulted in the establishment of only one first-class seismological station, the effort would be worth while. The need for the assignment of one full-time mathematical physicist for interpretation work was indicated as essential to such a program.

U. S. Coast and Geodetic Survey,
Washington, D. C.

THE SEISMOGRAPH AND FRICTION

Harry Fielding Reid

The friction at the marking point of seismographs recording on smoked paper has always been a difficulty. The direction of the frictional force is always changing. The elementary theory in which the friction is considered a constant force and at right angles to the lever has proved unsatisfactory. Galitzin attempted to improve it by assuming that the friction is a constant plus term proportional to the first and the second powers of the velocity, but he neglected the variation in the direction.

Direct experiments show that the friction is practically a constant, and that it is necessary to take account of its varying direction.

When the seismograph is recording a simple harmonic movement the direction of the movement varies harmonically; it can therefore be represented by a Fourier's series, in which the coefficients can be determined. Mathematical analysis shows that a very close approximation to the true effect can be obtained by neglecting all terms of the series except the first. The general equation of the seismograph can then be solved and the magnification of the earth movement determined. The formula obtained is similar to the known formula for the magnification of harmonic movements, except that it contains an additional term to take account of the friction. This term can readily be determined; and a series of tables makes it possible quickly to find the true magnification to a very close degree of approximation.

Johns Hopkins University,
Baltimore, Maryland.

SECTION OF METEOROLOGY

AN EXAMINATION OF THE DUST CONTENT OF THE ATMOSPHERE

HERBERT H. KIMBALL

At the Rome meetings of the International Geodetic and Geophysical Union in May, 1922, Sir Napier Shaw, President of the Meteorological Section, proposed the purchase of twelve Owen's Dust Counters for distribution to observatories in different countries affiliated with the Union, to be used in an international study of the dust content of the atmosphere.

The importance of this study is apparent from the close relation known to exist between atmospheric dustiness and visibility. Since visibility is one of the most important meteorological factors in aviation, an accurate forecast of this phase of the weather is desirable. Hence, the importance of accurate data on atmospheric dustiness.

Also, at intervals, volcanic eruptions throw vast quantities of dust high into the atmosphere, where it may float for months or even years, covering perhaps an entire hemisphere, and diminishing the intensity of incoming solar radiation. Also, it is suspected that at times dust of cosmical origin finds its way into our atmosphere. The adequate study of these questions demands international co-operation.

One of the twelve dust counters distributed as proposed above was received by the U. S. Weather Bureau, and since December 7, 1922, a count of the number of dust particles contained in a cubic centimeter of air has been made at Washington on each working day, generally at the American University, D. C., in a suburb about 3 miles northwest of the city, but sometimes at the base and top of the Washington monument, which is in a smoky section of the city.

The number of dust particles has been found to vary from about 100 to 4,000 per cubic centimeter.

With the minimum number of dust particles the Blue Ridge Mountains in Virginia, 50 miles distant, are clearly visible. With the maximum number of particles the visibility is ½ mile or less, depending upon the humidity of the atmosphere.

Dust counts have been made on two occasions during aeroplane flights. The first of these was to a height of 12,000 feet. The number of dust particles per cubic centimeter increased from a minimum of 499 at the surface to a maximum of 1,716 at a height of 9,000 feet, and fell off to 1,357 at 12,000 feet. On the second flight the number of particles per cubic centimeter was 678 at the surface, 1,741 at 3,000

feet, and 158 at 6,000 feet, which was at the base of a cloud layer from which rain commenced to fall shortly afterwards.

On the first flight there appeared to be a relation between air movements at different levels and dustiness.

While attended with difficulties, the feasibility and utility of dust counting from aeroplanes appears to be established. Further development of this line of work is expected.

U. S. Weather Bureau,
Washington, D. C.

THE METEOROLOGICAL WORK ON THE *JACQUES CARTIER*

E. H. Bowie

The *S. S. Jacques Cartier*, a freighter of 19,300 tons owned by the Compagnie Generale Transatlantique, in addition to functioning as a freighter, serves as a training school for prospective officers of the merchant marine.

Through the co-operation of the National Meteorological Service of France (Office Nationale Meteorologique) the *Jacques Cartier* has also been employed to test the practicability of maintaining a floating weather service for the collection of meteorological observations by radio, the issue of weather forecasts and warnings for the guidance of vessels navigating the oceans. Supervising Forecaster Edward H. Bowie of the Weather Bureau, on the invitation of the Compagnie Generale Transatlantique, extended through Captain Coyecque, professor and meteorologist of the Training School, made the voyage, New Orleans to Le Havre, February 11 to March 2, 1923, and returning from Boulogne to Santa Cruz del Sur March 13-30, 1923.

In charting the meteorological observations received on board the vessel main dependence was had on the observations broadcast from Arlington and the Eiffel Tower there being no time on either the outward or the inward voyage when the vessel was not in communication with one or both of these stations. The remarkable fact remains that it is possible at times for a vessel at sea to receive observations from Constantinople on the east to the Pacific coast on the west.

A single example of the weather information broadcast by the *Jacques Cartier* will convey an excellent idea of the scope of the meteorological activities of the vessel. The example follows:

Broadcast—March 20th—Greenwich Noon

Meteo. Jacques Cartier to all ships: North Atlantic weather situation March 20th, Greenwich noon. Pressure is high over northwestern Europe; 30.36 also from Bermuda to Azores and northward also over American Atlantic States. Trough of low pressure extending from Iceland (29.60) southeastward to Gibraltar

(29.50). Disturbance of great intensity (29.00) over Newfoundland moving east-northeastward.

Forecasts: Track, Azores to Gibraltar—unsettled weather eastern portion—northerly fresh winds, squally weather and overcast weather western portion. Stop. Tracks, Azores to English Channel—overcast weather and moderate easterly winds eastern portion—fresh or strong northerly winds and squally weather western portion. Stop. Azores region—fresh northerly winds moderating today and shifting to southeast and south tomorrow—overcast weather becoming fair. Track—Azores to Bermuda—Moderating northerly winds and fair weather between longitudes 30° and 42°. Southerly increasing winds shifting to southwest west of 42°, weather becoming overcast and probably rainy.

Advisory for westbound ships over transatlantic tracks west of Ireland to south of Grand Banks: Disturbance of great intensity (29.00) over Newfoundland moving toward Iceland will be attended by strong shifting winds today and tonight between longitudes 35° and 55° followed by fresh or strong northerly winds. Winds will shift tomorrow morning between 40° and 50°.

U. S. Weather Bureau,
Washington, D. C.

INDIAN SUMMER AS A CHARACTERISTIC WEATHER TYPE OF THE EASTERN UNITED STATES

ROBERT DE C. WARD

The author's studies of the weather maps which characterize Indian Summer weather have led him to recognize a type of pressure distribution which uniformly gives several days of weather commonly called Indian Summer. This pressure distribution was described as a more or less stagnant area of high pressure over the southeastern States and a weak cyclonic area passing slowly down the Saint Lawrence Valley. The resulting winds are light, and the moderate chill of the early morning and evening resulting from a fairly well marked diurnal range of temperature is swept away by the genial warmth of the light southerly winds, and by the strong isolation of the daytime.

He also emphasized the fact that the Indian Summer pressure type can and does occur in all seasons, but that the lack of precipitation, the prevailing haziness, and the temporary stagnation of the general atmospheric circulation are features most fully developed in autumn.

Harvard University,
Cambridge, Massachusetts.

TEMPERATURE INVERSIONS IN THE FREE AIR

W. J. HUMPHREYS

It is well known that a temperature inversion, that is, an increase of temperature with increase of elevation for a short distance, often occurs at the upper surface of a stratus cloud. Also that a similar

inversion is frequently found at about the same height when there are no clouds.

Some, perhaps all, of these inversions, especially those that occur on cloudless days, are caused, as Sir Napier Shaw has explained, by the turbulence of the lower air incident to winds. This stirring up of the lower air tends to bring it all to an equipotential temperature, hence to warm the under portion of the agitated layer and to cool the upper portion.

The less pronounced inversions in the higher portions of the atmosphere occur at boundaries between layers of wind that differ more or less in speed or direction, or, nearly always, both. In these cases turbulence, so far as it exists, warms, as explained above, the under portion of the agitated layer, and produces a temperature inversion, or, at least, a decrease in the temperature lapse with increase of elevation, at its upper surface.

However, since layers of air of different density glide over each other without rapid intermingling, it follows that the higher and less pronounced inversions of the free air are owing, chiefly, to the different origins of the winds immediately above and below them.

U. S. Weather Bureau,
Washington, D. C.

THE WIND FACTOR IN FLIGHT: AN ANALYSIS OF ONE YEAR'S RECORD OF THE AIR MAIL[1]

WILLIS RAY GREGG and LIEUT. J. PARKER VAN ZANDT

From an analysis of one year's records of the Air Mail Service between New York and San Francisco it has been found that at the average altitude of flight, about 1,500 feet above the ground, allowance must be made for a wind of 7 miles per hour from the west. In other words, westward flights will, on the average, be made at a speed of 14 miles per hour less than will eastward flights. A more detailed study of the New York to Chicago part of the route gives almost exactly the same wind factor as for the entire trans-continental route. This value of the wind factor has been verified by an examination of 8,667 free air observations with kites and pilot balloons, and the agreement is remarkably close. The importance of this agreement lies in the fact that, in fixing flight schedules in other regions or at other altitudes, dependence can be placed upon *either* method in case only one is available.

[1] Paper presented at Washington, D. C., before the American Meteorological Society on April 16, 1923, and the American Geophysical Union, Section (c) Meteorology, on April 18, 1923.

From a further study of the data, schedules that can be guaranteed 90% of the time have been determined for aircraft of any cruising speed between 50 and 150 miles per hour. In making up these schedules allowance has been made for head winds of 36 miles per hour or more in westward flight and 20 miles per hour or more in eastward flight, these being the wind speeds that are shown by kite and balloon records to occur 5% of the time. When they do occur, the flights will be somewhat delayed, but nevertheless completed. During the remaining 5% of the time flights are likely to fail altogether or be seriously delayed because of exceptionally unfavorable weather, such as severe rain or snow storms, poor visibility, etc.

Finally, a general wind curve has been prepared by means of which various schedules based on other percentage performances, greater or less than 90% and for different lengths of routes, may be determined. With the normal and high cruising speeds known quantities, allowance is made for an adverse wind such that the flight can be made in any desired time. The percentage frequency of this adverse wind is then read from the curve and thus is determined the percentage of the time that the desired schedule can be guaranteed.

U. S. Weather Bureau (Gregg),
Washington, D. C.
U. S. Air Service (Van Zandt),
San Diego, California.

PROGRESSIVE CHANGES IN THE FIELD OF METEOROLOGICAL OBSERVATIONS OF THE U. S. WEATHER BUREAU

A. J. Henry

Two maps were shown. The first portrayed the distribution of stations reporting by telegraph to the Central Office of the Signal Service in Washington, D. C., at the end of the first year of operation as a Federal Weather Service. The number of stations was 55. The second map showed the location of stations reporting to the Weather Bureau at the present time both by the electric telegraph and cable lines and by radio transmission from ships at sea. The number of stations reporting at the present is 332 distributed over widely separated parts of the globe. The Asiatic coast and the Philippines in the Far East, the Islands of the Pacific, Alaska and the West Indies are some of the regions from whence reports are received.

U. S. Weather Bureau,
Washington, D. C.

SECTION OF TERRESTRIAL MAGNETISM AND ELECTRICITY

REPORT OF THE COMMITTEE ON ATMOSPHERIC-ELECTRIC PHENOMENA AND MEASUREMENTS IN THE TROPOSPHERE AND STRATOSPHERE[1]

W. F. G. Swann, *Chairman*

Last year I reported that three members of the committee had undertaken the preparation of reports, Dr. Austin having promised a report on Wireless Strays, Dr. Blair a report on Instrumental Technique pertaining to upper air investigation, and Dr. Mauchly a report on the Diurnal Variations of the Atmospheric Electric Elements. Dr. Humphreys, to whom we already owe much of our knowledge concerning thunderstorms, promised to look into the question again at this stage, and see whether the time was ripe for a further report. He has concluded that the amount of new material which is not already summarized in existing reports is not sufficient to warrant the preparation of a further account at this time.

Dr. Austin has tendered his report, and has enriched our knowledge of the field by the publication of several papers on the subject of wireless strays and allied phenomena. Dr. Mauchly has also completed a valuable report on the Diurnal Variation of the Atmospheric Potential-Gradient.

In addition to the foregoing, individual members of the committee and those working in their laboratories have been independently active in investigations pertaining to the fields of our interests. It is perhaps unnecessary to give a detailed list of publications, but will suffice to say that the activities in question have comprised investigations on the Penetrating Radiation with special reference to work at high altitudes, on the Variation of Residual Ionization in Gases with Pressure, on the Nature of Ionic Recombination in the Atmosphere, on the Theory of Ionization by Rapidly Moving Particles, on the Action of the Heavisidean Layer, on Wireless Strays and Allied Phenomena, on the Diurnal Variation of the Potential Gradient, and on certain instrumental matters, for example, two investigations pertaining to the Ebert Ion-Counter. On all of these topics papers have appeared, have been presented at learned societies, or are in process of publication.

[1] Presented at the annual meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, April 18, 1923. Members of the Committee: L. W. Austin, W. R. Blair, W. J. Humphreys, S. J. Mauchly, R. A. Millikan, and W. F. G. Swann, chairman.

Last year certain tentative plans of a certain group of scientists for an Algæ Survey were brought to the attention of the Committee, and the opportunity for the prosecution of atmospheric electric observations was pointed out. The committee took cognizance of this information, and the section passed resolutions in sympathy with the project, promising more active co-operation at such time as plans had been more definitely formed by the organization. A letter has been received from one of the members of the organization, the purport of which is to the effect that the plans are temporarily in abeyance pending the consummation of a plan for financing the undertaking. The outcome is expected to be known in a very short time, but until that time no further action can of course be taken by the committee.

With regard to the Committee's plan for initiating the prosecution of atmospheric electric observations at such educational institutions as would be willing to undertake such work, I may say that a beginning has been made at the University of Minnesota, where Professor Zeleny has undertaken to pursue such work, and is making a beginning by installing a potential-gradient apparatus.

University of Minnesota,
Minneapolis, Minn.

REPORT OF THE COMMITTEE ON EARTH CURRENTS AND POLAR LIGHTS[1]

S. J. Mauchly, *Chairman*

The resumption, in February 1922, of earth-current registrations on both the N-S and E-W lines of the Ebro Observatory at Tortosa, Spain, following an interruption of several months, is considered most fortunate. While the need for the recent repairs and replacements is regretted, it is hoped that the changes made will not materially affect the value of the records when these are considered as additions to what is already the longest available series of continuous earth-current registrations. The resumption of registration is especially fortunate, also, because of the opportunity which it will afford for comparative study of the Ebro results with those soon to be obtained at the Watheroo Magnetic Observatory.

The Department of Terrestrial Magnetism of the Carnegie Institution of Washington has well under way the completion of its pre-

[1] Presented at the annual meeting of the Section of Terrestrial Magnetism and Atmospheric Electricity of the American Geophysical Union, Washington, April 18, 1923. Members of Committee: J. H. Dellinger, N. H. Heck, A. J. Henry, A. G. McAdie, S. J. Mauchly, chairman, and W. E. Parker.

liminary earth-current installation at Watheroo, Western Australia. The initial N-S and E-W lines for this installation are each 2 miles (3.2 km.) long and will constitute the only special installation for earth-current registration in the Southern Hemisphere. However, much interest attaches to the new installation apart from its geographic position and its availability as a comparison station. Briefly stated these additional features are as follows: (1) use of a multiple-point recording potentiometer as recording instrument; (2) automatic comparison of results from 1-mile (1.6 km.) and 2-mile (3.2 km.) lines, respectively, on both N-S and E-W lines; (3) comparison of results obtained by the use of overhead lines with those obtained from underground cables laid in insulating conduit. In addition, it is planned to make a resistivity survey of the entire region occupied by the system for each of the two seasons which differ most regarding the moisture and temperature of the soil, and to devote considerable attention to a study of the characteristics of several types of electrodes as regards suitability for continuous earth-current registration. The progress, to date, of the work on this installation makes it appear very probable that registration will be under way by the end of 1923.

As a result of the work of the MacMillan Baffin Land Expedition of 1921-22 there is now available a record of the aurorae observed from November 1921 to June 1922 at Bowdoin Harbor (64°4 N, 78°0 W) which was Dr. MacMillan's winter quarters. An auroral log is also being kept at Sitka, Alaska, by Mr. F. P. Ulrich, observer in charge at the Sitka Magnetic Observatory of the United States Coast and Geodetic Survey. Since aurorae are also being observed by the "Maud Expedition," under Captain Amundsen, the observations of Mr. Ulrich may prove to be of unusual value in conjunction with those from other stations co-operating with the Expedition.[3]

Some interest has been aroused in the possibility of a connection between aurorae and the phenomena of radio communication by the fact that the failure of a recent attempt to relay a radio message across Canada was accompanied by aurorae. It has been suggested by the Committee that interested radio operators who are suitably stationed could probably obtain valuable data which might be of assistance in determining the nature and magnitude of any interrelation which may exist between the two phenomena. For example, without going into the details of procedure, two co-operating observers, far apart along an approximate east and west line, could readily deter-

[3] At the time this report was prepared for publication Dr. MacMillan had completed preparations for an expedition to the Arctic regions in 1923–24, with an observational program including auroral observations similar to those made in 1921–22.

mine the existence of any effect upon communication between their stations and the nature and intensity of such effects. Precisely analogous remarks would apply to two observers separated by a great north-south distance. It is of course presumed that, of each pair of co-operative radio observers, at least one is at a sending station, and at least one in a region of high auroral frequency; also that stated periods of simultaneous recording of both radio and auroral conditions have been agreed upon by the observers. From a study of the data from several series of such co-operative observations, especially if they cover simultaneous observations during aurorae, for both the E-W and N-S directions, it should be possible to draw certain preliminary conclusions of value both from the view-point of radio communication and as regards indirect evidence concerning the ionization of the upper regions of the atmosphere during aurorae. [The foregoing ideas will be carried out, so far as possible, during the ensuing year, through the use of a specially prepared form by radio stations in Canada relaying radio messages to and from the MacMillan Arctic Expedition, 1923-24.]

Department of Terrestrial Magnetism,
Carnegie Institution of Washington,
Washington, D. C.

PROGRESS REPORT OF THE COMMITTEE ON RELATIONS BETWEEN TERRESTRIAL MAGNETISM, TERRESTRIAL ELECTRICITY, AND SOLAR ACTIVITY[1]

LOUIS A. BAUER, *Chairman*

Measures of Solar, Magnetic, and Electric Activity.—The compilation and computation of measures of solar activity, magnetic activity, and electric activity, based on all available data, have been continued by the Department of Terrestrial Magnetism. Thanks to the co-operation of Professor Wolfer of Zürich, we are promptly supplied with his relative sun-spot numbers, which are published as soon as possible in the *Journal of Terrestrial Magnetism and Atmospheric Electricity* in order to make the data available to others. We have at present the final sun-spot numbers through 1918 and the provisional ones complete from 1919 to March 1923, inclusive. From these data, it appears that for the present cycle, the minimum sun-spot activity occurred in 1913, and an extraordinarily large maximum (103.9 for

[1] Presented at the annual meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, April 18, 1923. Members of Committee: C. G. Abbot, Louis A. Bauer, chairman; R. L. Faris, George E. Hale, and C. F. Marvin.

the mean of the year) in 1917; it is not yet possible to say whether the minimum has again been reached. The mean number for 1922 was 14.7, and the mean monthly numbers for January to March 1923 are, respectively: 5.3, 1.6, and 4.0. There has been no such high maximum as that of 1917 since 1870, when the mean number for the year was 139.1. For the first time since 1871 has the monthly mean number exceeded 150, as it did in August 1917, viz, 154.5.

An important publication during the year has been that by Hale on *"Invisible Sun-spots."*[2] At the Rome 1922 meeting of the International Astronomical Union, various committees on solar phenomena were combined into one under Hale's chairmanship; there are 21 widely-distributed members, among whom, of our Union, are Hale, Abbot, and Bauer.

Abbot has reported to the Committee the general results of the *solar-radiation observations*, October 1920 to September 1922, made at the two stations of the Smithsonian Institution, Harqua Hala, Arizona, and Montezuma, Chile. He calls attention to the high solar-constant values until 1922, usually exceeding the normal value of about 1.94 calories. Nothing so marked as the change in 1922 to low values has occurred since the observations were begun at Mount Wilson in 1905. (Dr. Abbot also personally presented his report at the meeting of the Section; it will be found published, in expanded form, in the *Monthly Weather Review* for February 1923, pp. 71-81.)

Marvin reports continuation of the attempts to find *relationships between meteorology and solar activity*. An outline of this work was presented by him at the meeting of the American Meteorological Society at Washington, on April 16, 1923.

Bauer has continued the disclosing of *relationships between terrestrial magnetism, terrestrial electricity, and solar activity*. The twelve-year series of observations at the Observatorio del Ebro, Tortosa, Spain, 1910-1921, pertaining to earth currents, atmospheric electricity, and terrestrial magnetism, have been subjected to discussion and analysis, as also the available atmospheric-electric data at other observatories. The following general conclusions[3] are drawn:

1. The relationship between sun-spot activity and atmospheric electricity turns out to be, for locally undisturbed stations, as definite as in the case of terrestrial magnetism; the sun-spot influence on the periodic variations of the atmospheric potential-gradient is, in general, as great as on the periodic variations of terrestrial magnetism; and as concerns the effects on the absolute values, the sun-spot

[2] *Proc. Nat. Acad. Sciences*, July 1922, pp. 168-170; see also abstract in the *Year Book of the Carnegie Institution of Washington* for 1922, p. 212.

[3] See *Terr. Mag.*, vol. 27, 1922, p. 30.

influence is about 300 times greater in atmospheric electricity than in terrestrial magnetism. The potential gradient of atmospheric electricity, and, presumably, the Earth's total negative electric charge, is furthermore subject to an annual or secular change, which may vary in magnitude and sign from one sun-spot cycle to another.

2. The potential gradients of earth currents, as recorded at the Ebro Observatory, 1910–1920, varied during the sun-spot cycle, decreasing in the direction of normal flow of current with increased sun-spot activity; the diurnal range, however, increased with increased sun-spot activity.

3. There is evidence of a similar six-hour wave in atmospheric electricity, earth currents, and terrestrial magnetism.

The bearing of conclusion 1 on the question of the origin and maintenance of the Earth's electric charge needs no elaboration here.

The interesting six-hour wave referred to in the third conclusion, the amplitude of which increases with increased solar activity, just as does that of the 24-hour wave, has received further attention. The Fourier analysis of the potential gradient of atmospheric electricity has been made in the Department of Terrestrial Magnetism for each month of the mean year of the 11-year series for the Ebro Observatory. Once more the six-hour wave is found to be of peculiar interest. For every month of the mean year, excepting November, December, and January, its amplitude is larger than that of the eight-hour wave, and on the average for the year the amplitude is about one-third that of the 24-hour wave and nearly half that of the 12-hour wave. Its phase angle, relatively, shows the same constancy within less than half-hour, during the year, as does the 12-hour wave. It is not possible to enter into further details, but my colleague, Mr. Mauchly, will also have something interesting to report in his paper regarding a six-hour wave. Unfortunately previous analyses have frequently stopped with the third term, and it was assumed that the series would thereafter converge. The flaring up of the amplitude of the fourth wave, even at such an exceptionally favorably located station as is the Observatorio del Ebro, is a matter of considerable interest.

Another feature of interest is the double wave shown by the annual variation in the diurnal variation of the potential gradient, as disclosed by the combined amplitude, as well as by the amplitudes of the 12-hour and the 6-hour waves separately. The maximum amplitudes occur near the equinoctial months, the minimum near the solstitial months. Striking similarities in the annual variation of the following phenomena have now been shown to subsist: Magnetic disturbances, earth-current disturbances, polar-light frequencies, atmospheric-electric disturbances, and the earth-effect on solar activity.

Even the lag in the second maximum, occurring in October instead of September, is shown by all phenomena.[4]

The annual variation of other geophysical quantities has likewise required attention in the pursuit of the relations sought for by the Committee. For example, the annual variation of the potential gradient of atmospheric electricity, as observed at stations distributed over the Earth from the Arctic to the Antarctic regions, shows phenomena similar to those resulting from a system of vertical electric currents caused by the translatory motion of an electrically-charged sphere through the ether, for example, by the charged Earth during its orbital motion about the Sun; this hypothesis is being further investigated. The available data reveal the following types:

Type *a*. From the Arctic regions to about parallel 33° North and from about 40° South to the Antarctic regions, the maximum potential gradient occurs near the December solstice and the minimum near the June solstice.

Type *b*. In the region from about 33° North to 40° South, or over about half of the Earth's surface in the lower latitudes, some of the stations show a reversed annual variation to that of type *a*, hence, maximum potential gradient near June solstice and minimum near December solstice.

Type *c*. In region for *b*, or between *a* and *b*, there are certain stations showing a mixed type of *a* and *b*.

On the average, from the Arctic to the Antarctic, the annual range of the potential gradient is about 60 per cent of the average potential gradient for the year; the data in the North Hemisphere seemingly indicate that the range decreases as the region for type *b* is approached. There are some indications that the bounding parallels between regions of types *a* and *b* may be found to be magnetic parallels, rather than geographic ones.

Department of Terrestrial Magnetism,
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Washington, D. C.

REPORT OF THE COMMITTEE ON MAGNETIC STANDARDS, AND INSTRUMENTS AND METHODS OF AERIAL MAGNETIC MEASUREMENTS[1]

J. A. Fleming, *Chairman*

Comparisons of magnetic and electric methods for determining the horizontal intensity of the Earth's magnetic field.—With respect to

[4] See *Terr. Mag.*, vol. 26, 1921, pp. 113–115, vol. 27, 1922, p. 27.

[1] Presented at the annual meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, April 18, 1923. Members of Committee: C. G. Abbot, J. P. Ault, S. J. Barnett, L. J. Briggs, J. A. Fleming, chairman, and N. H. Heck. The Committee carried on its duties by correspondence, and the report was compiled largely from sub-reports submitted by Messrs. Ault, Briggs, Fleming, and Heck.

magnetic standards, the outstanding work during the year was the completion of an indirect comparison between three electro-magnetic instruments for determining the horizontal intensity of the Earth's magnetic field, viz, the Schuster-Smith magnetometer of England, the Watanabe electric magnetometer of Japan, and the Carnegie Institution of Washington sine galvanometer designed by Dr. Barnett and constructed by the Department of Terrestrial Magnetism. These comparisons were obtained by Messrs. Parkinson and Brown of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington using standard magnetometers of the Department for the comparisons at the National Physical Laboratory, Teddington, England, and at the magnetic observatory, Kakioka, Japan; the magnetometers were later carefully compared with the sine galvanometer at Washington. The results show that the Schuster-Smith magnetometer and the sine galvanometer give values differing by less than 1/10,000 part of the value of the horizontal intensity, H, of the Earth's magnetic field, or less. The Watanabe instrument, however, for some reason indicates values greater by 1/3,000 part of H, but field instruments were used for this work and there is somewhat greater uncertainty in the result than for the other comparisons.

The provisional international magnetic standard for H adopted in 1914 by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, as based on all available data respecting the results of inter-comparisons of magnetic instruments made the world over by various organizations and the Department, was found from extensive comparisons made at Washington, D. C., in June and August 1921 and again in February and March 1923 to be in practical agreement with the sine galvanometer. Thus it is found that the provisional H-standard gives results agreeing within 1/5,000 part of H or less with those from electro-magnetic methods (excluding Japan), and hence is well within the limit of error for all practical and theoretical requirements.

Dr. Chree reports that the comparisons of his standard magnetometer with the Schuster-Smith magnetometer also show substantial agreement between the magnetic and electric instruments.

Maintenance of standards provisionally adopted by the Department of Terrestrial Magnetism.—The results of comparisons at Washington between the standard magnetometer and earth inductor and magnetic instruments of various designs, as well as the comparisons with the electric instrument referred to above, show a satisfactory maintenance of the standards well within the limits of error of observation. The compilations of results again show that for the desired precision it is necessary to exercise close control on the magnetometer

constants, and particularly on changes in the moment of inertia of the oscillating magnet and its suspension and on possible changes in the distribution factors for the magnet systems used.

Comparisons of magnetic standards at observatories.—Comparisons of magnetic standards have been made by the Department of Terrestrial Magnetism, since the last report of the Committee, at 14 observatories in France, England, Scotland, Denmark, Finland, Germany, Holland, Belgium, Spain, Portugal, Algeria, Egypt, Japan, and Australia. Mr. W. C. Parkinson of the staff of the Department of Terrestrial Magnetism made the comparisons at 12 of these observatories, while Messrs. F. C. Brown and D. G. Coleman of the Department secured the comparisons in Japan and Australia. The results indicate again the necessity of frequent control comparisons, with well-determined standards, for all observatories. It is particularly emphasized, as a result of these comparisons, that the earth inductor should replace the dip circle for the determination of magnetic inclination.

Magnetic standards of the United States Coast and Geodetic Survey.—Since the establishment of the Cheltenham magnetic observatory the regular absolute instruments of that observatory have been regarded as the standard instruments of the U. S. Coast and Geodetic Survey and all other absolute instruments of the Bureau have been referred to them either directly or indirectly. In the case of field instruments, direct comparisons are usually made at the beginning and end of each field season; in the case of the instruments at other observatories, direct comparisons have been made at every opportunity, as when an instrument is sent to the office for repairs, but main dependence is placed on indirect comparisons through field instruments.

Comparisons at Cheltenham with instruments of the Department of Terrestrial Magnetism showed that the Cheltenham instruments gave results in substantial agreement with the provisionally adopted international magnetic standards of that Department, so far as dip and declination were concerned, but that for horizontal intensity the results were too great by about one part in one thousand. The same thing was indicated by the average of the various field magnetometers of the Coast and Geodetic Survey. Accordingly it was decided, beginning with 1913, to adopt as the standard for horizontal intensity the results with magnetometer No. 26 at Cheltenham diminished by 1 part in 1,000.

The constancy of this H-standard has been controlled by repeated comparisons with other magnetometers, in particular magnetometer No. 40, an India Survey pattern instrument held in reserve as a spare observatory magnetometer.

In 1918 this spare magnetometer was compared with the standard magnetometer of the Department of Terrestrial Magnetism and was then sent for comparison to the Tucson, Honolulu, and Sitka observatories, and returned for another comparison at Cheltenham in 1921. In 1922 a magnetometer of the Carnegie Institution type was compared successively at Cheltenham, Sitka, Tucson, and Cheltenham.

As regards dip, a spare earth inductor has not heretofore been available for indirect comparison between the one at Cheltenham and those at the other observatories, but one is expected from the maker shortly. However, direct comparisons were made in 1922 with the instruments from Porto Rico and Tucson when they were sent to the office for repairs.

Additional control of the instruments at the Honolulu observatory was obtained through comparison with the instruments of the *Carnegie* in 1921.

These various comparisons indicate a satisfactory constancy of the observatory instruments in recent years, but it is not safe to assume that such a condition will continue indefinitely. The same remark applies with greater force to field instruments, which are subjected to more variable and less favorable working conditions.

Horizontal intensity is the element for which the instrumental constants are most likely to undergo change; of these the moment of inertia and the distribution factors require most attention. The apparent variation of the distribution factor from month to month and from year to year deserves careful study.

Development of instruments and methods for aerial measurements.—At the Bureau of Standards considerable work has been done in the development of an Earth-Inductor Compass, designed especially for use in airplanes. The instrument differs from previous compasses of this type in the following particulars:

(1) It employs a null method for its indications, and hence possesses the advantage of sensitivity characteristic of null methods as a class.

(2) An iron core is used in the earth inductor to reduce the size of the instrument.

(3) A method of distant electrical control is used, enabling the earth inductor itself to be located as remotely as necessary to avoid disturbances from magnetic material.

(4) Rolling and pitching errors are eliminated.

The armature is cross-shaped with long thin cores to reduce as much as possible the self-demagnetizing effect. The cores are made of 3½ per cent silicon steel with a length 20 times their diameter. The winding is of the usual closed coil pattern. The shaft of the armature is kept in a vertical position by supporting it from gimbal rings. The

bearings of these rings are frictionally damped and the armature is weighted. By this means a good rolling and pitching compensation is obtained. The armature is wind driven, using cup-shaped vanes, the connection being made through a flexible shaft. The instrument may be located in the rear part of the fuselage away from the local magnetic disturbances of the engine.

Two sets of brushes of 90 degrees take off current from a 4-section commutator. A closed potentiometer circuit is provided in the form of a square and the 4 brushes are connected to the 4 corners of this square. Two wiping contacts 180 degrees apart draw current from the square frame and are connected to the galvanometer. These wiping contacts are controlled by a dial mounted coaxially with the frame and carrying compass graduations. A position of the dial can always be found in which the galvanometer current is zero, and there is a one-to-one correspondence between this neutral position of the dial and the angle of orientation of the aircraft. A square resistance frame is used to avoid a non-uniformly graduated dial which would result from a circular frame.

It has been found practicable to use this compass in the air for an accuracy of perhaps 2 or 3 degrees.[2]

Attempts have been made at the Bureau of Standards to use an especially devised dip needle in the air with the idea of determining the latitude of the aircraft approximately through reference to charts of magnetic dip. These attempts have proved unsuccessful owing to the peculiar effects of the vibration of the aircraft on the motion of the dip needle. The subject is, however, still under investigation. An earth inductor for determining dip has been constructed and is now under test. The level base of reference in this instrument is a bubble.

One of the chief efforts of Army and Navy Aviation experimenters during the past year has been to try to improve the magnetic compass. Several officers from these Departments have visited the Department of Terrestrial Magnetism and have been given such assistance as was possible to further their efforts in this direction. The attitude of practical aviators seems to be to demand a better compass, and some have felt that if the compass could be depended upon for 90 per cent of the time, all other instruments could be thrown overboard.

Dirigibles would seem to be the better adapted for aerial magnetic work than airplanes on account of their longer cruising radius, convenience for mounting observing outfits, greater stability, etc. The problem of supplying a non-inflammable gas is not yet solved. Helium is too expensive as yet for general use and is regarded as not necessary

[2] A full description of the instrument may be found in *Proc. Am. Phil. Soc.*, vol. 61, No. 1, 1922.

for commercial use. As an extra safeguard against fire, the all-metal airship is strongly recommended. The all-metal envelope is a protection against static electricity. If a hole is torn in this envelope and the gas catches fire, it will burn as a jet without exploding the airship if the hole does not enlarge. If all-metal airships become the rule, the mounting of magnetic measuring instruments would be complicated unless special metals are used in the construction of certain parts of the airship.

The present tendency in the development of aerial navigation instruments is to emphasize the need of perfecting the radio compass and direction-finder instead of magnetic instruments.

The Loth magnetic cable is being successfully developed to guide an airship from point to point, and in case of landing in a fog the cable is used to guide the aviator to the landing field.

Department of Terrestrial Magnetism,
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REPORT OF THE COMMITTEE ON RELATIONS BETWEEN LOCAL MAGNETIC DISTURBANCES, GRAVITY ANOMALIES, AND GEOLOGICAL FORMATIONS[1]

D. L. HAZARD, *Chairman*

During the past year considerable time has been devoted to the study of the relation between local magnetic disturbances and geological formations by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, and the U. S. Coast and Geodetic Survey.

The months of July, August, and September were spent by Mr. H. W. Fisk of the Department of Terrestrial Magnetism and his assistant, Mr. J. T. Howard, in Bermuda, where a special study of the magnetic disturbance there was made.

Observations at five primary stations of 1907 show that the secular change between 1907 and 1922 is sensibly the same at all stations as regards horizontal intensity and dip. In declination there is evidence of a sensible difference in different regions.

Diurnal-variation observations carried out simultaneously at two stations in regions of maximum and minimum values of each element indicate that the diurnal variation in horizontal intensity is not affected by the anomaly to a degree measurable by available field methods.

[1] Presented at the annual meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, April 18, 1923. Members of Committee: D. L. Hazard, chairman; N. M. Fenneman, G. W. Littlehales, and W. J. Peters.

The diurnal-variation curves for declination where this element has widely different values appear to be identical, but for points where the horizontal intensity has widely differing values there is evidence of a slight difference.

Observations were made at over 100 secondary stations and in greater detail in regions of special interest from which it is concluded that the disturbance may be separated into two parts: (*a*) The primary disturbance affecting large areas, connected with the underlying volcanic structure. (*b*) The secondary disturbance affecting very limited areas, apparently arising from magnetic properties of the soil of varying thicknesses. The intermediate coral limestone was found to be not magnetic.

At the request of Mr. W. R. Crane, Superintendent of the Southern Experiment Station of the Bureau of Mines, an investigation was undertaken by the U. S. Coast and Geodetic Survey during the summer of 1922 to determine whether deposits of non-magnetic iron ore could be detected by means of magnetic observations. Some observations which Mr. Crane had made indicated the possibility that such a method might be used with success, and it was considered worth while to test it by using a more sensitive instrument and more refined methods.

The investigation was carried out in Alabama, the observations comprising three parts: (1) Observations in the brown iron ore district, about 30 miles southwest of Birmingham. (2) Observations at Red Mountain Gap, just outside of Birmingham. (3) Detailed observations near a large specimen of brown iron ore (limonite) and a large specimen of red iron ore (hematite) on the grounds of the University of Alabama at Tuscaloosa.

The owners of the brown iron ore property kindly furnished data regarding the underlying strata as derived from the drill records.

The results indicate that iron ores of the character under investigation do not produce an effect on the earth's magnetism large enough to be detected by ordinary magnetic observations even when the greatest care is taken. In the brown iron ore district the results at the different stations do not differ more than is to be expected, taking into account the error of observation and the uncertainty of the correction for diurnal variation, and there appears to be no relation between the small observed differences and the underlying ore bodies revealed by the drilling. The results at Red Mountain Gap show greater differences, but there is no apparent relation between them and the thickness of the ore body.

The vessels of the Coast and Geodetic Survey, operating in southeastern Alaska, continued during 1922 the investigation of areas of

marked local disturbances in that region with a view to the determination of more details as to their extent and magnitude both on land and over water areas; these data will be valuable for the study of the relation of the observed disturbances to geologic formation as soon as information on the latter subject is available.

During the season of 1922 a number of gravity stations were established by the Coast and Geodetic Survey in Kansas, Oklahoma, and Texas at the request of the Director of the U. S. Geological Survey in order to throw some light on subsurface densities of the earth's material. A computation and adjustment of the gravity stations and a reduction of the stations for topography and compensation were completed during the month of March 1923, and the resulting gravity anomalies were furnished to the Director of the Geological Survey, where they will be studied by Dr. David White.

No additional information has become available since last year regarding the possible relation between gravity anomalies and local magnetic disturbances, and, until new instruments or new methods are available which will make it possible to secure gravity determinations more rapidly and in less accessible places than is possible with the pendulum, much progress is not to be expected. The Geophysical Laboratory, in co-operation with the Coast and Geodetic Survey, has been at work on the problem of devising such an instrument, but it is still in the experimental stage.

U. S. Coast and Geodetic Survey,
Washington, D. C.

REPORT OF ROME MEETING OF THE SECTION OF TERRESTRIAL MAGNETISM AND ELECTRICITY OF THE INTERNATIONAL GEODETIC AND GEOPHYSICAL UNION, MAY 1922[1]

LOUIS A. BAUER, *Delegate*

A well-attended meeting of the Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union was held at Rome, May 4 to 9, 1922. Representatives from Australia, Belgium, Brazil, France, Great Britain, Italy, Japan, Poland, Spain, Sweden, and the United States were present at various sessions. Besides discussion of the Agenda, which contained leading questions pertaining to terrestrial magnetism and electricity, reports were presented by national and other committees and by leading investigators.

Professor Tanakadate (Japan) tendered his resignation as president

[1] Presented at the meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, April 18, 1923.

of the Section, because of his inability to attend to the duties involved. Dr. Charles Chree (Great Britain) was then chosen president and Professor Luigi Palazzo (Italy) vice-president. According to the statutes, the secretary and director of the Central Bureau, Dr. Louis A. Bauer, continues in office until the next meeting, which will be held at Madrid, Spain, in 1924. Directors J. Jaumotte (Belgium) and Ch. Maurain (France), and Professor A. Tanakadate (Japan) were elected additional members of the Executive Committee. It was agreed that administrative matters should be left to the officers of the Section, who constitute the Bureau.

Five committees were appointed: (1) Committee on Magnetic Surveys and International Comparisons of Instruments (Louis A. Bauer, chairman); (2) Committee on Observational Work in Atmospheric Electricity to report on Objects, Instruments and Methods (G. C. Simpson, chairman); (3) Committee on Measures of Magnetic Characterization of Days; (4) Committee on Best Methods, Instruments, and Compilations of Polar Light Observations; (5) Committee to Consider and Report on Best Methods and Instruments for Earth-Current Observations (Sir Arthur Schuster, chairman). The appointment of chairmen of Committees 3 and 4 was deferred pending the early entrance into the Union of additional countries.

The representatives of the American Geophysical Union on these international committees are: Louis A. Bauer and N. H. Heck (No. 1); W. F. G. Swann (No. 2); R. L. Faris (No. 3); J. A. Fleming (No. 4); and S. J. Mauchly (secretary of No. 5).

The results of the meeting were embodied in the form of 20 Resolutions, which are published in the secretary's general report.[2]

Department of Terrestrial Magnetism,
Carnegie Institution of Washington,
Washington, D.C.

THE BERMUDA ANOMALY[1]

H. W. Fisk

The peculiar interest in the local magnetic disturbance in Bermuda arises from the geological conditions with which it is connected. The island is a submerged mountain of volcanic origin

[2] *Terr. Mag.*, vol. 27, 1922, pp. 89-100. For the complete transactions see Bulletin No. 3 of the Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union (Johns Hopkins press, Baltimore, Maryland, October, 1923).

[1] Abstract of paper presented before Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, April 18, 1923.

covered with a coral limestone cap which, at the only point where a boring has been made, extends 250 feet below sea-level.

The Department of Terrestrial Magnetism made a magnetic survey of the island in 1907 and repeated a part of the work in the summer of 1922, carrying out at the same time some special investigations relating to local disturbances. In this later work extensive tests were made which failed to discover any magnetic properties in the limestone either in fragments or in large masses. The magnetic distribution, however, indicates that, besides the general disturbance affecting widely separated areas, there are others of local character that have their origin much nearer the surface. The compass-variometer, an instrument designed and constructed by the Department for the detection of small differences of horizontal intensity, was used to study a few limited areas in detail. In one such there were found differences of as much as 700 gammas (0.00700 C.G.S.) within less than 200 feet horizontal distance. There was no evidence of an artificial source for this disturbance. The soil at various points on the island was examined and found to be magnetic, though the distribution of these local disturbances could not be directly related to the depth or to other apparent properties of the soil. There are, therefore, a major or primary source of disturbance lying deep in the lower structure of the submerged mountain, and other minor or secondary sources lying in or near the surface, probably in the soil.

Diurnal-variation observations with field instruments were made in declination simultaneously by two observers stationed at two points between which the difference was near a maximum. The simultaneous differences remained practically constant, and no evidence of any change in the diurnal variation either in range or phase due to the existence of the disturbance was found. A similar series of observations was made for the inclination using earth inductors, obtaining a value every 15 or 20 minutes, and for horizontal intensity using the method of deflections at one distance repeated at similar intervals. For these elements good diurnal-variation curves were obtained, although, because of the magnitude of unavoidable errors of observation, they were not a satisfactory basis for any conclusions.

In the course of the work in 1907, five stations were chosen as repeat stations and carefully marked for reoccupation. Two of these were reoccupied in 1910 by the *Carnegie* party, and all were reoccupied in 1922. The small differences in the 15-year change in inclination and horizontal intensity at the different stations show a slight tendency to vary with the value of the element. When the

results from the nearest magnetic observatories are available, by which an approximate reduction of observations at all stations to a common epoch may be made, it may be possible to determine whether this tendency is real. In the case of the declination, the evidence is positive. The two stations which were occupied in August 1907, in January 1910, and in August 1922 were found to have declinations which differed by 3° 53′, 3° 59′, and 4° 18′ on the three occasions respectively, showing a steady increase in the difference with time. This increase seems to be related in some way to the declination at the two stations and is suggested also by the results at the other stations; for if the 15-year change is plotted for each of the five stations, using the declination as abscissae, the points fall near a line within limits on the order of the uncertainties of determination. It is hoped that a further refinement of the intensity observations may make it possible to reveal a connection between this phenomenon and the components of the disturbance field.

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THE EARTH-INDUCTOR COMPASS[1]

P. R. Heyl

The earth-inductor compass for airplanes, as developed at the Bureau of Standards contains several novel features:

1. A null method is used for the indications. As long as the ship holds the prescribed course, the needle of the indicating galvanometer reads zero. A deviation from the course on either side is accompanied by a corresponding movement of the needle, which thus acts as a turn-indicator.

2. An iron core is used in the indicator, enabling the instrument to be designed of a small size.

3. Rolling and pitching errors are eliminated by a specially damped gimbal suspension.

4. A means is provided of distinguishing between north and south, or, in general, between any two opposite bearings.

5. A distant electrical control is used, by means of which the inductor can be located at a distance from the engine, and the course-setting device and indicator be located at the instrument board.

Bureau of Standards,
Washington, D. C.

[1] Abstract of paper presented before Section (d) of the American Geophysical Union, April 18, 1923.

MAGNETIC METHODS FOR LOCATING IRON ORE[1]

N. H. Heck

At the request of Dr. W. E. Crane, Superintendent, Southern Experiment Station, Bureau of Mines, Birmingham, Alabama, observations were made by the Coast and Geodetic Survey to determine whether or not so-called non-magnetic iron ore affected the magnetic needle sufficiently to use this method in the investigation of iron ore deposits. The possibility was rather doubtful, but the commercial importance of such a method warranted the investigation.

The total intensity was obtained from plain dip, and dip with loaded needle, the dip needle not being reversed in polarity during the season, and the loaded needle lying nearly horizontal. The reduction factor and temperature coefficient of loaded needle were determined at Cheltenham and verified at Birmingham. The total intensity was obtained from the expression $F=P \cos I' \csc (I-I')$, where F=total intensity, I' is dip with loaded needle, I is dip, and P is constant.

P reduced to 30° C. shows very slight change. It was found that an increase of 1° C. lowers loaded end of needle 3.09 minutes of arc. The regions of red ore (hematite) and brown ore (limonite) were each examined; observations were also made over large specimens of each ore in an undisturbed region.

Probable error of dip was 1 minute; loaded dip, 2 minutes; total intensity, 30γ. Diurnal variation was taken from Cheltenham, one magnetic storm occurring during observations.

Results: In brown ore region, variations in observations 10 feet apart were as great as for 100 feet; mean difference between adjoining poles was 3′.9 with maximum difference of 9′.7 in the loaded dip. The total range over the entire area was 18′. Less range was found in the other cases.

Conclusions: The observed differences are too near those of the probable error of observation to be significant. The needle is slightly affected by the presence of ore, but not sufficiently for interpretation.

Areas of Marked Local Disturbance

The recently discovered large areas of local disturbances in southeastern Alaska are described. The Port Snettisham area is described in the Journal of Terrestrial Magnetism for December 1922. An area of 70 square miles in Lynn Canal has been found to have local disturbances with a range of declination of 25°. A new area was

[1] Abstract of paper presented before Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, April 18, 1923.

found in Union Bay, Ernest Sound, with variation of 38° from the normal value for the region. Seven square miles of this area were investigated.

In other cases the investigation covered both land and water areas, the land observations being along the shores. At Port Snettisham and Union Bay two points of actual disturbances were indicated by observations. For the water areas the north end of the needle is drawn towards the shore where the maximum disturbance is noted, except in one case in Chilkat Inlet, where the needle apparently pointed away from the disturbed region and is deflected towards the area where normal values were observed—this is probably a local effect.

Attention was called to the large deflections in depths of water of from 400 to 800 feet. Need for geological investigation in this region was indicated.

U. S. Coast and Geodetic Survey,
Washington, D. C.

OBSERVATORY EQUIPMENT FOR RECORDING PHOTOGRAPHICALLY THE CONDUCTIVITY OF THE AIR[1]

S. J. Mauchly

The atmospheric-electric program at the observatories of the Department of Terrestrial Magnetism at Watheroo, Western Australia, and Huancayo, Peru, provides for separate continuous records of each of the unipolar conductivities, λ_+ and λ_-. The conductivity recording equipment for a given observatory consists of two subsidiary units, each of which is a modification of the well-known Gerdien conductivity apparatus similar, in general, to that described by Swann,[2] in 1917, but including certain features and improvements which have resulted from several years' experience, at Washington, with the original apparatus.

The records are obtained photographically by means of a quadrant electrometer and suitable accessories. One pair of quadrants of the electrometer is connected to the insulated central cylinder of the main condenser and the other to the case of the electrometer, which is maintained at a potential of the order of 100 volts. The two pairs of quadrants are permanently connected through a high-

[1] Abstract of paper read at the annual meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, April 18, 1923.

[2] See "Apparatus for Automatically Recording the Electric Conductivity of the Air," by W. F. G. Swann, in "Annual Report of the Director of the Department of Terrestrial Magnetism" for the year 1917, *Year Book of the Carnegie Institution of Washington*, 1917, p. 279.

resistance radioactive cell, of the type developed in the Department of Terrestrial Magnetism by Swann and the author,[2] and the apparatus is thus readily adjusted for a linear relation between electrometer deflection and conductivity. The arrangements for calibration and for the elimination of spurious effects due to leak and to radioactive materials in the atmosphere are similar in principle to those described by Swann (l.c.).

In each of the two subsidiary units the "outer cylinder" of the portable Gerdien apparatus is represented by the middle section of a vertical air-flow tube extending through both the roof and the floor of a specially designed instrument house. The air flow in each tube is maintained by a fan driven by a small electric motor, both the motors and the electric recording lamps being operated from a 32-volt storage battery. Air is taken in through a suitable hood above the roof and discharged into an open space about 40 cm. high between the raised floor and the level of the ground. There is thus little chance of air being drawn a second time through the apparatus, and the maintenance of satisfactory insulation is greatly facilitated by the fact that dust and moisture from the air stream are prevented from depositing on the insulators of the electrometers and accessory apparatus.

As a result of changes in the fan and the lower part of the tube, the rate of air flow has been increased sufficiently to insure against saturation current between the inner and outer cylinders even under the most severe recording conditions.

Characteristic performance data were given, and normal conductivity records obtained at the Watheroo Magnetic Observatory were shown.

Fuller description will appear in the *Journal of Terrestrial Magnetism and Atmospheric Electricity*.

Department of Terrestrial Magnetism,
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PROGRESS OF THE MAGNETIC SURVEY OF THE UNITED STATES[1]

D. L. Hazard

The first general magnetic survey of the United States, begun by the Coast and Geodetic Survey in 1900, was practically completed in 1915. It involved the determination of the three magnetic

[2] *Terr. Mag.*, vol. 22, 1917, pp. 1–21.

[1] Abstract of paper presented at the annual meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, April 18, 1923.

elements, declination, dip, and horizontal intensity, at nearly every county seat in the country, and the reoccupation from time to time of a sufficient number of repeat stations in all parts of the country, to determine the change of the magnetic elements with lapse of time and to make it possible to reduce the observed values to any desired common epoch. The collected results of this survey reduced to January 1, 1915, were published in United States Magnetic Tables and Magnetic Charts for 1915, together with magnetic charts showing graphically the distribution of the declination, dip, horizontal intensity, vertical intensity, and total intensity for that date.

This general survey showed that there are many regions in the United States where more detailed observations are required to develop the irregular distribution of the earth's magnetism, the so-called "areas of local disturbance." Since 1915 the field work has been largely devoted to the continued occupation of repeat stations and the establishment of more stations in disturbed areas. During and immediately after the war the force of observers was so small that little field work could be done other than to keep the secular-change data up to date, but in 1922 it was possible to resume the filling-in process.

While there has been an increasing number of requests for information regarding the earth's magnetism, particularly as to the change of declination with lapse of time in connection with the reestablishment of lost boundaries, it is clear that the use of the magnetic stations of the Coast and Geodetic Survey and the data available in the office of the Bureau is still far short of what it should be. Accordingly in 1922 the names of all county surveyors, so far as possible, were obtained from the State authorities and a circular letter was sent to each one having two objects in view: First, to call attention to the data in this office at his disposal, and second, to find out the present condition of the magnetic stations in his vicinity. This has resulted in a large increase in the number of requests for information and has brought out the fact that a large percentage of the magnetic stations have disappeared or are no longer suitable for use. Up to the end of March, 1923, reports had been received from 441 stations (about one-tenth of the whole number) of which 254 are no longer available. The establishment of new stations to meet local demands will be one of the most important practical features of the work in the immediate future.

Work of this character had already been undertaken early in 1922 in response to the request from the Florida Engineering Society for the establishment of a meridian line and magnetic station at every county seat.

The work of 1922 also included an investigation in Alabama of the possibility of using magnetic instruments for the location of deposits of non-magnetic iron ore.

The investigation of areas of local disturbance in southeastern Alaska was continued over both land and water areas, the observations being limited to declination.

The magnetic observatories at Vieques, P. R., Cheltenham, Md., Tucson, Ariz., Sitka, Alaska, and Honolulu, Hawaii, have continued in operation. Receiving sets have been in use at Cheltenham and Honolulu for some time for obtaining wireless time-signals, and one is about to be installed at the Porto Rico Observatory on Vieques Island. This Observatory soon may have to be discontinued or removed, due to poor living conditions at Vieques.

At the Cheltenham Observatory preparations are under way for an investigation of the effect produced on magnetic variometers by earthquake waves, a test of Professor Reid's theory, and an investigation of the control of the temperature coefficient of variometers, based on Mr. Hartnell's discussion of theory of such variometers.

At the Rome meeting of the International Section of Terrestrial Magnetism and Electricity a resolution was adopted "that it is desirable there should be in every country at least one observatory making systematic atmospheric-electric observations * * *." The Coast and Geodetic Survey is in sympathy with this resolution and is prepared to undertake such observations as soon as the necessary instruments can be secured, at either the Cheltenham or the Tucson Observatory. It also desires to add the study of earth currents to the program of one of its observatories when funds are available for the purpose.

In the reduction and publication of the observatory results several new methods have been adopted to facilitate the work and reduce the cost. These methods were discussed in detail.

Among the important publications may be mentioned "Compass Surveys" and "Magnetic Declination in the United States for January 1, 1920," issued primarily for the use of local surveyors.

The paper on "Horizontal-Intensity Variometers" by George Hartnell, Magnetic Observer, published in 1922, gives in detail the mathematical theory of the instrument and will be of great assistance in its operation and adjustment.

The routine computations and publication of field and observatory results have been carried on systematically, the latest publications

of observatory results being for 1919 and 1920 and of field results for 1921.

U. S. Coast and Geodetic Survey,
Washington, D. C.

SUMMARY OF RESULTS OF A RECENT ANALYSIS OF THE EARTH'S MAGNETIC FIELD FOR 1922[1]

LOUIS A. BAUER

A new analysis of the Earth's magnetic field was made for 1922 by the writer, with the assistance of various members of the Department of Terrestrial Magnetism, as free as possible from assumptions as to the systems composing the entire magnetic field, and restricted, for the present, to the region of the Earth (86 per cent), from 60° North to 60° South. A spherical harmonic series to the sixth degree, and in some cases to the seventh, was established separately for each of the rectangular components, X (positive towards North), Y (positive towards East), and Z (positive towards nadir); the Earth was treated as a spheroid of revolution. Only some of the chief conclusions can be given here; for details, reference must be made to the full publication:[2]

It is found that for a satisfactory representation of the observed data, it is necessary to recognize the existence of an internal magnetic system, I, an external system, E, and a non-potential system, N, or of three equivalent systems, X, Y, Z. The I-system constitutes about 94 per cent of the total magnetic field, and E and N, each about 3 per cent.

The secular variation of the Earth's magnetism is caused both by changes, with lapse of time, in the direction of magnetization and by changes in the intensity of magnetization; the latter quantity has been steadily diminishing during the past 80 years at the annual average rate of about 1/1,500 part.

The north end of the magnetic axis of the I-system during the past 80 years has been moving slowly towards the west, and apparently at the same time slowly towards the equator. Were we to suppose that the magnetic axis made a complete revolution around the Earth's axis of rotation, the indications are that the period would not be a few hundred years, but many thousand years.

For the Earth's internal uniform magnetic field, the following data

[1] Abstract of paper presented at the meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, April 18, 1923.

[2] See *Terr. Mag.* for March-June 1923, pp. 1-28, and for September 1923, pp. 61-81.

apply for 1922: The magnetic moment, M, is 8.04×10^{25} C.G.S.; the components of M, respectively parallel and perpendicular to the Earth's axis of rotation, are $M_p = 7.88 \times 10^{25}$ C.G.S., and $M_e = 1.60 \times 10^{25}$ C.G.S.; $M_p = 4.93\ M_e$. Were the Earth's magnetism uniformly distributed through the Earth, as it probably is not, the average intensity of magnetism would be 0.074 C.G.S. The magnetic axis intersects the North Hemisphere in latitude 78° 32′ North and longitude 69° 08′ West of Greenwich.

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NOTES ON THE ORIGIN OF THE EARTH'S MAGNETIC AND ELECTRIC FIELDS

W. F. G. Swann

No abstract is given for this paper which was presented at the meeting of the Section of Terrestrial Magnetism and Electricity, April 18, 1923, as the gist of it is contained in the address by the author before the second general session of the Union, April 17, 1923 (see pp. 60–68).

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Minneapolis, Minnesota.

OUR PRESENT KNOWLEDGE CONCERNING THE ATMOSPHERIC DISTURBANCES OF RADIO-TELEGRAPHY[1]

L. W. Austin

Our present knowledge concerning the atmospheric disturbances of radio-telegraphy is very limited, but in the following I have attempted to make a brief résumé of the known facts and generally accepted hypotheses.

Atmospheric disturbances, popularly called static, form the chief obstacle to the progress of radio-telegraphy and telephony. They give rise to troublesome noises in the telephone receivers, which frequently make the reception of signals at great distances impossible, even in the case of the most powerful transmitting stations. They are generally most violent during the warmer months, and are especially severe in the tropics. They differ in strength from year to year, and their intensity usually increases rapidly with the wave-length to which the receiving apparatus is tuned.

[1] Sub-report of Committee on Atmospheric-Electric Phenomena and Measurements in the Troposphere and Stratosphere presented at the annual meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, April 18, 1923.

The disturbances have been classified by Eccles according to their sound in the telephones as clicks, hissing, rumbling, and crashing. The clicks and hissing are of comparatively little importance, the first being thought to be due to distant flashes of lightning, and the second to the discharge of dust, snow, or rain, striking the antenna.

The rumbling type (grinders), which is the most common type of disturbance, is generally believed to consist of strongly damped electrical wave trains or of untuned single pulses. That this type of disturbance has sometimes a certain amount of tuning is shown by the fact that the individual discharges are not always heard simultaneously at different wave-lengths, but it is believed that the discharges are so numerous that since they occur at different frequencies, they form a kind of disturbance spectrum and thus appear in the receiving apparatus at every wave-length to which the antenna may be tuned. While nothing is definitely known as to the exact nature of the source of the rumbling disturbances, it is believed that they are probably produced in the upper atmosphere by electrical readjustments. The resulting electrical waves expand in a more or less spherical manner until the lower portions of the wave front strike the earth when they spread out guided by the earth and move off with a wave front which soon becomes practically vertical, exactly like the electrical waves started from the transmitter of an airplane. The more powerful rumbling disturbances seem to come frequently from definite centers which often appear to lie above mountainous regions; for example, a large proportion of these disturbances which have been noted along the coast of Oregon and Washington appear to come from the direction of Mt. Rainier. Other well-marked centers have been observed in the mountains back of San Francisco and San Diego. The centers mentioned appear to be nearly constant in position and have been continuously active since their first discovery in 1920. It is believed that there is also a center of great energy somewhere in southern Mexico which frequently produces receiving difficulties throughout the eastern United States where disturbances from the Allegheny Mountains are also noticed. Among other reported sources of rumbling disturbances are large cities, perhaps on account of their ascending currents of heated air, thunder clouds, though here they are apparently unconnected with the visible lightning flashes, which produce clicks, and the advancing edges of rain areas. It may be said that, in general, the rumbling disturbances more commonly originate above the land as ships far out at sea are comparatively little troubled by them.

The intensities of disturbances of the rumbling type seem to be closely connected with the seasonal variations in the height of the

sun's path. Some observations in Africa, reported by Dr. R. B. Goldschmidt and R. Braillard, tend to show that radio stations close to the equator have two well-marked maxima during the year at the time when the path of the sun passes through the zenith.

When the disturbances are directive and come from a direction different from that of the signal which is being received, it is often possible to eliminate a large part of the disturbances and thus improve the reception by making use of unidirectional receiving apparatus. Unfortunately it generally happens that there are secondary centers, such as local clouds or near-by mountains, which act upon the receiving station from several directions at the same time.

Some situations have been found, notably in California, where the disturbances come almost entirely from one point. In these places reception from the direction of the Pacific Ocean can be made nearly free from atmospheric troubles.

In addition to the rumbling disturbances, crashes are often heard in the telephones which seem to differ in origin and character from the rumbling type. The difference in sound of the two types is not easily distinguishable for untrained observers, since the rumbling is frequently preceded by a crashing noise. The true crashing disturbance, however, is not followed by rumbling. There is little evidence that the crashes are directive in character, while there are a number of observations which tend to show that they occur simultaneously at widely distant stations; for example, at San Francisco and Honolulu. It has been suggested that they may be connected with solar outbursts, although there is little direct proof to this effect. Sometimes they appear to occur in large number on days when earth-current disturbances are noted on telegraph and cable lines. It is also thought by radio operators that the crashes are entirely untuned in character, since the individual crashes are observed frequently simultaneously on widely different wave-lengths.

The Chief Problems of Atmospheric Disturbances

1. There is need of systematic daily observations on the intensity of the atmospheric disturbances at a large number of points in all parts of the earth. It is desirable, where possible, to have this intensity measured in terms of electric voltage on the antenna expressed in volts per meter height. Eventually recording apparatus should be devised for automatically taking these observations.

2. Measurements are also needed on the prevailing direction of the directive types of disturbances at widely scattered stations. As soon as possible, recording instruments should be used for this purpose. A direction recorder has, I believe, already been constructed in Eng-

land. These observations will probably show daily and seasonal shifts of prevailing direction, and will eventually indicate certain points as disturbance centers.

3. When these disturbance centers are identified, a study should be made of the meteorological and electrical conditions prevailing, which will perhaps throw light on the conditions under which the disturbances are produced.

4. Observations should be made on the simultaneity of individual disturbances at widely distant points, identifying as far as possible the type of disturbance.

5. The question of the directivity of the crashing type should be settled.

When sufficient information regarding these points has been collected, comparisons can be made between the disturbances and other natural phenomena, solar activity, the earth's electrical and magnetic phenomena, and those of seismology and volcanology.

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Washington, D. C.

THE WORK OF THE INTERNATIONAL UNION OF SCIENTIFIC RADIO TELEGRAPHY[1]

J. H. Dellinger

The International Union of Scientific Radio Telegraphy, begun in July 1919, is organized: (1) To promote the scientific study of radio communication. (2) To aid and organize researches requiring co-operation on an international scale and to encourage the discussion and publication of the results of such researches. (3) To facilitate agreement upon common methods of measurement and the standardization of measuring instruments. The work is actually carried on through National Sections, which have been formed in the United States, Belgium, England, France, Italy, and Norway. Steps are being taken to create such committees also in Australia, Holland, Japan, and Spain.

The meeting at Brussels in 1922 organized four international "commissions" as follows: (1) Methods of measurement and standards. (2) Radio wave transmission phenomena. (3) Atmospheric disturbances. (4) "Liaisons."

The American Section, under the auspices of the National Research Council, in Washington, is made up of an Executive Committee and

[1] Abstract of paper presented before the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, April 18, 1923.

six technical committees. These technical committees are: (1) Radio Wave Transmission Phenomena. (1a) Variations of Radio Wave Direction. (2) Atmospheric Disturbances. (3) Methods of Measurement and Standards. (4) Measurement of Radiation Causing Interference. (5) Electron Tubes. (6) "Liaison."

There is fruitful work for many years in the programs as outlined for the committees and it should have value not only for the better understanding and use of radio but also in the problems of geophysics, composition of the atmosphere, etc. Observations at sea are likely to be of particular value, as they have been fewest in the past, and because the radio phenomena are in general less complicated than on land.

It is believed that radio is unique among the few fields having special adaptability to a large-scale international research program. The phenomena that must be studied are world-wide in extent, and yet are in large measure subject to control of the experimenters. It is a field of work that has large possibilities for the future, and the surface only has been touched in the work done so far. Great progress can be made in the understanding of radio phenomena when widespread observations are taken, similar to the organized observational work on weather, earthquake, and terrestrial magnetic phenomena.

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Washington, D. C.

ON THE DIURNAL VARIATION OF THE POTENTIAL GRADIENT OF ATMOSPHERIC ELECTRICITY[1]

S. J. Mauchly

Two years ago the author read before this section a paper giving the results of an analysis based upon all the diurnal-variation observations for potential gradient, conforming to an adopted standard, which had then been made aboard the *Carnegie*.[2] It may be recalled that when the observations for the Atlantic, Pacific, and Indian Oceans, respectively, were tabulated in the usual manner, according to the local time of observation, the mean curves showed the diurnal variation over each of the oceans to consist *almost entirely* of a well-defined 24-hour wave although the times of occurrence of, say, the maximum phase of this wave differed greatly for the several oceans.

[1] Sub-report from the Committee on "Atmospheric-Electric Phenomena and Measurements in the Troposphere and Stratosphere," read at the annual meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, April 18, 1923.

[2] *Bulletin of the National Research Council*, No. 17, 1922, pp. 73–77.

It was also shown that mean curves, for the several oceans, obtained after first referring each series of observations to G.M.T. indicated a roughly simultaneous occurrence of maximum and of minimum, respectively, over all the accessible ocean areas. It was further shown that the mean diurnal-variation curves from many leading observatories, especially those corresponding to high latitudes and to winter months in the Northern Hemisphere, were in better agreement when plotted according to G.M.T. than according to local time.

Since the publication of the foregoing conclusions additional observations aboard the *Carnegie* have increased by 50 per cent the number of ocean observations of the diurnal variation of the potential gradient. The results obtained from a separate reduction of the new material have confirmed those obtained in 1921, both as regards the preponderance of a 24-hour wave progressing approximately according to universal time and also as to the times of occurrence of its characteristic phases.

Enough data are now available to justify grouping according to time of year in order to determine whether the diurnal variation undergoes any material changes during the course of the year. Four mean curves, each representing all the observations in a given three-month period, show only minor differences in the variation. The general constancy as regards the chief features of the diurnal variation is perhaps most readily indicated by the results of a Fourier analysis which was made of the data corresponding to the several curves. It should be noted that the observations were all referred to G.M.T. and, therefore, that the phase angles given in the table refer to 0^h, midnight, G.M.T. (The absolute values of the potential gradient given in the table are subject to an increase of the order of 20 per cent on account of a corresponding increase in the adopted reduction factor over the one originally used.)

TABLE 1.—*Fourier analysis of the diurnal variation of the potential gradient (P) from observations aboard the Carnegie 1915–1921.*

$P = P_m + c_1 \sin(\theta + \varphi_1) + c_2 \sin(2\theta + \varphi_2) + \cdots$, θ is counted from 0^h, midnight G.M.T. In the table c_1, c_2, etc., are expressed in percentages of P_m.

Months	P_m	φ_1	φ_2	φ_3	φ_4	c_1	c_2	c_3	c_4	c_2/c_1
	V/m	°	°	°	°	%	%	%	%	
Feb.–Apr.	114	197	273	208	352	19	4	1	1	0.24
May–July	94	163	209	119	223	10	7	2	1	0.72
Aug.–Oct.	97	168	218	250	337	16	4	1	2	0.24
Nov.–Jan.	105	204	225	243	14	14	2	4	1	0.15
Year	102	187	221	228	348	15	4	1	1	0.25

While there is an apparent variation in ϕ_1 with time of year it should be borne in mind that the number of observations now available for each quarter is not sufficient to insure the reality of such differences as are shown in Table 1. Similarly, the large value of c_2 for the months *May, June, and July,* may be due, at least in part, to the fact that this quarter is represented by somewhat fewer observations than the others.

A special method was employed to determine, if possible, whether any part of the diurnal variation of the potential gradient over the oceans enters in as a local-time effect. For this purpose a separate study was made of the observations from 24 selected days (12 pairs), the places of observations represented by each pair differing in longitude by 180°. A mean curve, *according to local time,* of these "compensated" observations shows a distinct 6-hour wave, but no evidence of any other wave of appreciable amplitude. According to Fourier analysis the amplitude of the 6-hour wave is about 3 per cent. of the mean-of-day value, P_m, and the corresponding phase angle, at local midnight, is zero. These results, so far as they go, are in good accord with the 6-hour wave found by L. A. Bauer in his analysis of the potential-gradient data from the Ebro Observatory[8] although they must, of course, be accepted with reserve on account of the relatively small amount of observational material from which they are derived.

With the confirmation of the occurrence, in the diurnal-variation of the potential gradient over the oceans, of a 24-hour wave progressing approximately according to universal time, increasing interest attaches to the investigation of the possible occurrence of a similar phenomenon at land stations. For this purpose a comparison was made of the results of all available Fourier analyses of the diurnal variation of the potential gradient as published by various authors from time to time, together with the results of many new analyses, made in the Department of Terrestrial Magnetism and based on published data which had not, heretofore, been thus utilized. For the purpose in hand the main comparison of stations was based on the phase angles (φ_1) of the first harmonic (24-hour wave) at 0^h, midnight, G.M.T., rather than on the corresponding phase angle (φ_1) at local midnight. The comparisons were carried out for each of the solstitial and equinoctial quarters, respectively. Space prevents giving here more than a summary of the results for months corresponding approximately to the northern winter, shown in Table 2. The symbols used in this table are briefly as follows: φ_1, the phase angle of the first harmonic at local midnight; $\overline{\varphi}_1$, the corresponding phase angle at 0^h, midnight, G.M.T.; G_1, the G.M.T.

[8] *Terr. Mag.*, vol. 27, 1922, p. 28.

TABLE 2.—*Diurnal variation of potential gradient for months of northern winter. Results of Fourier analysis*

Place	Months	Years	Lat.	Long.	φ_1	$\bar{\varphi}_1$	G_1 (G.M.T.)	φ_2	c_1	c_2	c_2/c_1
			°	°	°	°	h.	°	%	%	
Karasjok	Nov.–Jan.	1903–04	69.3N	25.6E	189	215	15.7	155	35	14	0.41
Edinburgh	Oct.–Mch.	1912	55.9N	3.2W	222	219	15.4	161	21	6	0.30
Potsdam	Dec.	1904–08	52.4N	13.1E	206	219	15.4	179	22	5	0.25
Kew	Nov.–Feb.	1898–12	51.5N	0.3W	209	209	16.1	181	12	11	0.90
Paris	Nov.–Feb.	1895–99	48.8N	2.3E	223	225	15.0	206	22	10	0.47
Munich	Nov.–Dec.	1905–10	48.1N	11.6E	241	253	13.1	187	26	15	0.56
Kremsmünster	Nov.–Mch.	1902–11	48.0N	14.1E	212	226	14.9	172	30	13	0.43
Davos	Nov.–Jan.	1909–10	46.8N	9.8E	217	227	14.9	189	35	16	0.44
Lyons	Dec.–Feb.	1885–90	45.8N	4.8E	220	225	15.0	183	13	10	0.76
Trieste	Dec.–Feb.	1904–05	45.6N	13.8 E	226	240	14.0	212	55	5	0.09
Ebro	Dec.	1910–20	40.8N	0.5E	224	224	15.1	193	22	9	0.40
Baltimore	Oct.–Feb.	1885–86	39.3N	76.6W	255	178	18.1	239	14	9	0.66
Washington	Jan.	1918–21	39.0N	77.1W	257	180	18.0	161	19	9	0.48
Algiers	Nov.–Feb.	1912–17	36.8N	3.1E	234	237	14.2	114	32	8	0.26
Batavia	Oct.–Mch.	1887–90	6.2S	106.8E	70	177	18.2	220	64	23	0.36
Rio de Janeiro	Sept.–Feb.	1910–11	22.9S	43.2W	286	243	13.8	171	32	23	0.72
Melbourne	Dec.	1858–62	37.8S	145.0E	63	208	16.1	210	25	24	0.96
Cape Evans	Nov.–Jan.	1911–12	77.6S	166.4E	66	232	14.5	243	21	4	0.22
Carnegie						204	16.4	—	14	2	0.15

corresponding to the maximum phase of the 24-hour wave; φ_2, the phase angle of the second harmonic at local midnight; and P_m, c_1, and c_2, respectively, the mean-of-day value, and amplitudes of the 24-hour and 12-hour waves, expressed in percentages of P_m.

From an inspection of Table 2 it appears that the G.M.T. corresponding to maximum phase of the 24-hour wave (G_1) shows no greater variations than might quite properly be attributed, in the main, to local causes. For both equinoctial quarters the agreement is nearly as good as during the months of northern winter. Only during the months which correspond to the northern summer is there a wide scattering as regards the G.M.T. values of G_1. However, even during this quarter, the majority of the stations show only small changes in G_1, from the values for the remainder of the year. Throughout the year there are relatively few exceptions to the general rule that only at stations for which c_2 is greater than c_1 is there marked departure from the value of G_1 as derived from the corresponding observations aboard the *Carnegie*.

There seems, thus, no reason to doubt that a 24-hour wave, progressing approximately according to universal rather than local time is in evidence at most land stations as well as over the oceans, and that its apparent absence at any given station is, in general, due to the fact that it is masked by local effects of greater magnitude.

Fuller publication and discussion of the results of this investigation will appear in the *Journal of Terrestrial Magnetism and Atmospheric Electricity* for September 1923.

Department of Terrestrial Magnetism,
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SECTION OF OCEANOGRAPHY

REPORT OF THE COMMITTEE ON SEDIMENTATION AND MARINE DEPOSITS

T. WAYLAND VAUGHAN, *Chairman*

The members of this Committee are H. F. Moore, C. E. Van Orstrand, H. S. Washington, and T. Wayland Vaughan, Chairman. During the year two meetings were held, one at the residence of the Chairman on November 17, 1922, in conjunction with the members of the Committee on Sedimentation of the Division of Geology and Geography, N. R. C., resident in Washington, and one at Ann Arbor, Mich., on December 27, 1922, in conjunction with a general meeting of the Committee on Sedimentation above mentioned.

During the past year the following investigations on marine sediments have been conducted or begun in the United States.

Delta deposits at the mouth of the Mississippi River, by A. C. Trowbridge, for the U. S. Army Engineers. A report setting forth the results of his investigations has been prepared by Professor Trowbridge and it is hoped that it will be published. A considerable body of valuable information on the physical features of the sediments, on the effect of salt water on the flocculation of river-borne material, and on the influence of currents in distributing the material on the sea-bottom was acquired.

Deposits in Pago Pago Harbor, Samoa.—M. N. Bramlette has described a set of bottom samples from Pago Pago Harbor for the Department of Marine Biology of the Carnegie Institution of Washington. Mechanical analyses of the samples were made by the U. S. Bureau of Soils and chemical analyses were made by L. G. Fairchild of the Chemical Laboratory of the U. S. Geological Survey. A report on these samples, accompanied by maps and diagrams, is almost ready for the printer.

Coral reef sands from the Bahamas.—An elaborate study of sands from behind the reef off Cocoanut Point, Andros Island, Bahamas, has been completed by M. I. Goldman of the U. S. Geological Survey, and a report has been prepared for publication. This study was made according to the method of Doctor Goldman's report on samples from Murray Island, Australia, in Carnegie Institution of Washington Publication 213.

Deep-sea samples from off the Bahamas, the Caribbean Sea, and off the south coast of Central America.—The mechanical analyses of about 50 samples from the regions above indicated have been made by the U. S. Bureau of Soils and the amount of material in a colloidal

state in each estimated from the amount of water-vapor absorbed. Chemical analyses of fractions of the same samples have been completed by L. G. Fairchild of the U. S. Geological Survey. T. W. Vaughan has examined and classified a number of the samples but has not been able to complete a report on them.

Muds from the shoal waters of the Bahamas and Florida.—Much additional work has been done on the calcium-carbonate muds of the shoal waters of the Bahamas and Florida, as follows: Mechanical composition by the U. S. Bureau of Soils; the bacterial flora and the bacterial precipitation of calcium carbonate by K. F. Kellerman and N. R. Smith of the U. S. Bureau of Plant Industry; and the physical features and contained remains of organisms by T. W. Vaughan. C. B. Lipman concludes from studies at Tortugas, Florida, that denitrifying bacteria do not precipitate calcium carbonate from pure ocean water; but the experiments of Messrs. Kellerman and Smith show that these organisms do precipitate calcium carbonate when a small amount of organic matter is added to the bottom mud, and chemical analyses by E. T. Erickson of the U. S. Geological Survey show that the bottom mud contains organic matter. The actual rôle of bacteria in precipitating calcium carbonate has not been determined, but the fact seems established that as bottom living organisms they are competent agents.

Beach pebbles along the New England coast.—C. K. Wentworth has published a paper on this subject as one of the Shorter Contributions to Geology of the U. S. Geological Survey.

Bottom deposits of the Gulf of Maine.—An investigation of the bottom deposits of the Gulf of Maine has been initiated through cooperation between the U. S. Bureau of Fisheries, the U. S. Geological Survey, and the U. S. Bureau of Soils. The mechanical analyses are being made at the Bureau of Soils, and the chemical analyses are being made in the Chemical Laboratory of the Geological Survey. A report will be prepared by W. S. Burbank, who will describe the samples and discuss the significance of the results.

Miscellaneous investigations.—Besides the studies above enumerated, a number of other investigations need to be noticed. R. C. Wells has continued his experiments on the cementation of calcium-carbonate sands; E. M. Kindle has published in the Journal of Geology a paper on mud cracks on the surface of calcium-carbonate muds in southern Florida, and R. W. Sayles has made qualitative experiments to determine the possibility of the occurrence of seasonal banding in marine deposits. The last subject has also been considered by A. C. Trowbridge and Max Littlefield in connection with their studies of the sediments at the mouth of the Mississippi River. The discussions

at the joint meeting of the Committee on Marine Sediments and of the Committee on Sedimentation of the Division of Geology and Geography, N. R. C., will be mimeographed and distributed as a part of the report of the Committee on Sedimentation.

This Committee is gratified to report so much progress on the investigation of marine deposits during the past year.

U. S. Geological Survey,
Washington, D. C.

REPORT OF COMMITTEE ON CONFORMATION AND TOPOGRAPHY OF OCEANIC BASINS

G. W. Littlehales

In connection with a contribution published among the communications to the First Pan-Pacific Scientific Conference, entitled "The Problem of Ascertaining the Configuration of the Basin of the Pacific Ocean," occasion has been taken to refer to the manuscript sheets of the bathymetrical chart of the world, prepared by the U. S. Hydrographic Office, setting forth the authentic deep-sea soundings, as evidence of the small extent to which the oceanic basins have been sounded and as showing the inadequacy of existing measurements to define the contours of configuration beyond the continental shoulder. While it must be remembered that not all the recorded soundings could be entered in some parts of this chart, yet, where none are laid down, none have ever been measured: and in regions where soundings are represented, if all the recorded soundings could be included instead of the selection which is given where the room does not allow more to be shown, there would yet be too few in general to serve for the delineation of contours of configuration of the bottom of the ocean. Nevertheless, there are some parts of the ocean where the number and distribution of the measurements have proved sufficient to afford an approach toward a fulfilment of this purpose, notably in the lane extending from California to Hawaii, of which a contoured map and profiles are published in United States Senate Executive Document No. 153, 52nd Congress, 1st Session, being the Report of the Results of the Survey for the Purpose of Determining the Practicability of Laying a Telegraphic Cable between the United States and the Hawaiian Islands. And, recently, the method of measuring the depth of the ocean by means of the Sonic-Depth Finder has been employed in the survey of a tract of the bottom of the Pacific Ocean 34,000 square miles in extent, bordering the coast from San Francisco to San Diego and extending seaward to the depth of 2,000 fathoms. A map of the topography of the ocean floor resulting from this sur-

vey by two vessels of the Navy in the course of 34 days was presented with the report.

This map is of great significance to the Committee on Conformation and Topography of the Oceanic Basins because it seems to indicate that the mapping of the oceanic basins has been brought within the range of feasibility. Other important accessions, from American sources, to the accumulated data in relation to the configuration of the oceanic basins have resulted from the measurements by sonic depth finder at close intervals across the Atlantic from Narragansett Bay to Gibraltar and thence through the Mediterranean Sea to the Suez Canal, of which profiles were presented.

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A MATHEMATICAL THEORY OF THE TEMPERATURE DISTRIBUTION IN WATER DUE TO SOLAR RADIATION, EVAPORATION AND CONVECTION

GEORGE F. MCEWEN

The distribution of heat, chemical properties, and substances dissolved in the water of reservoirs, lakes and oceans depends both upon external agencies and the internal processes of conduction, and diffusion. But the latter phenomena taking place in large bodies of water, are entirely different in kind from what controlled laboratory experiments reveal. The well-known laws of conduction and diffusion deduced from *laboratory* experiments can not be carried over into the *field* where the corresponding phenomena are of a large scale type peculiar to nature.

This paper presents an attempt to formulate a set of assumptions, underlying phenomena of heat conduction, based upon field observations, and to deduce from them corresponding mathematical formulae involving the external agencies, solar radiation and evaporation as well as the internal convective or alternating circulation of the water. The convective process resulting in a mingling of small portions of the water is always present, and at the same time a general drift or current either vertical or horizontal may exist and can be taken into account in the theory, but is not considered here. A brief statement of assumption follows. The solar radiation penetrating the surface decreases in intensity according to a simple exponential law. The rate of evaporation is the same throughout the whole surface area, and the resultant increase in specific gravity of any small volume at the surface destroys its equilibrium, thus causing it to descend. It is assumed that the amount of increase in specific gravity

required to cause the descent of any particle varies throughout the surface. Thus, the number of particles of a given specific gravity descending at any time decreases as the specific gravity increases, while the downward velocity of each is assumed to be proportional to the difference between its specific gravity and the general average value at that level. There is a continual disturbance of the equilibrium resulting in a succession of overturning motions each following a sufficient increase of stress in the system. Only those particles whose specific gravity exceeds the average value at any given level will descend below that level, and displace upward an equal amount of water per unit time.

Mathematical formulae corresponding to these assumptions have been derived. By means of these formulae, from observations of temperature and salinity alone, the rate of evaporation at the surface, the rate at which solar radiation penetrates the surface, and the absorbtion coefficient of radiation in water can be computed. Preliminary computations based upon both lake and ocean data have given values in good agreement with what would be expected from available direct observations of their values. However, it is necessary for a satisfactory test of the theory that all these related quantities be simultaneously *observed* in the same body of water. But, the approximate verification already obtained indicates that the basal idea already developed is applicable, although certain refinements of the theory will likely be found to increase the accuracy of computed results.

If the mechanism of the convective circulation thus deduced from principles of mechanics and heat conforms closely enough to actual conditions, the same theory also affords a means of dealing with phenomena of diffusion and even fluid friction. Such an extension of the application of the theory may be expected from the generally accepted idea that both diffusion and viscosity "so called" in large bodies of water are really due to convection or the interchange of water particles or small portions of water having different properties.

A paper presenting, in detail, the development of the theory and its application to a variety of field data is in preparation.

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La Jolla, California.

NOTE ON THE RELATIVE ACCURACY OF THE DETERMINATION OF MEAN SEA-LEVEL, AND EXTENSIVE LINES OF LAND LEVELING

W. Bell Dawson, M.A., D.Sc., M.Inst.C.E.

To obtain mean sea-level from tidal observations, a summation of the heights at each hour throughout the year is made; the heights being measured from any low-level plane of reference which is maintained at a constant elevation. The average value of this summation is the elevation of mean sea-level above the plane of reference. The variation between the determination in any one complete year and in a long series of years, will rarely exceed 0.10 foot, plus or minus.

The average value of mean sea-level, based on 3 or 4 consecutive years of observation, has thus a high degree of accuracy; provided that the observations are taken with the precautions explained in the paper. The variation from year to year, is undoubtedly actual, as can be shown; but its cause we need not discuss, as we are here dealing merely with the question of accuracy.

An error of 0.10 foot as above, corresponds with an error in land leveling, as determined by the usual formula, on an extent of some 300 or 400 miles. Hence there is an advantage, in equating errors in leveling, in checking when practicable to do so, with determinations of mean sea-level on the seacoast, within the limits of this distance.

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ESTUARY TIDES: A COMPARISON OF METHODS OF COMPUTATION

W. Bell Dawson, D.Sc., F.R.S.C., *Superintendent of the Tidal and Current Survey of Canada*

Estuary tides are of great importance; because many of the largest harbours of the world are in estuaries. Ocean transportation is thus carried as far inland as possible. The situation of estuary harbours seems to be determined by the point on the estuary where the tide attains its maximum range, before the height of the tide begins to be cut off by the river slope.

The most generally used method for the calculation of tide tables, is the harmonic analysis; by which tidal constants are determined, to serve as a basis for the prediction of tides in a future year. This method answers well so long as the tide curve is symmetrical, as it is on the open coast of the ocean. The tidal constants are then almost wholly of an astronomical character, in accordance with the positions of the sun and moon. But when the tide passes over some

hundreds of miles of relatively shallow water, or up an estuary of any considerable extent, other elements become too large to be ignored. These elements are hydraulic in character rather than astronomical; since they are due to the balance between the momentum of the tidal streams and the retardation of bottom and lateral friction; as well as to the contrary flow of the river against the incoming tidal undulation. The tide curve itself is modified; becoming steeper during the rise of the tide and longer and flatter during the fall.

To meet these changed conditions, additional factors are introduced into the harmonic series, known as "Compound tides" and "Overtides." But with those usually employed, the resulting predictions are often unsatisfactory. From investigations by the Tidal Institute of Liverpool, it would appear necessary to introduce an indefinite number of additional terms for these Compound tides and Overtides; and in analysing for these, it could not be known in advance which of them would prove important and which of them negligible. The analysis itself thus becomes almost hopelessly tedious; and further, when these constants are found, there is no Predicting Machine which could handle so many of them as would result. (Discussion invited on this question.)

In supplying tidal data for large regions, especially where there are land-locked areas and estuaries, it is only for a few carefully selected reference stations that primary predictions are made from tidal constants determined by harmonic analysis. Computations for secondary tide tables and for the prediction of the turn of tidal streams, must in turn be based on differences of time and on ratios; which are not necessarily constant, but may vary in some lunar period. The question therefore arises whether estuary ports cannot better be dealt with on this principle. The methods that have been tried for Quebec, in the St. Lawrence estuary, will furnish a good example of the two ways of arriving at the result desired.

There were 19 years of tidal observation at Quebec which had been submitted to harmonic analysis; but the predictions obtained were not satisfactory. The whole record was therefore re-examined, as the ice conditions in some winters caused serious disturbance; and in the spring months of some years the high freshet levels were not likely to be well represented by the harmonic terms (Sa and Ssa) which are intended to give this variation. Accordingly, seven years were selected from this long series which appeared to be quite satisfactory. The average constants derived from these years were used to fill gaps in seven other years in which some winter months had to be cut out because of unreliable curves due to ice obstruction in the river; and these seven years were then submitted to re-analysis. Even with

this revised basis comprising the fourteen best years, the predictions are not what they should be; as there is at times a discrepancy of as much as 30 minutes as compared with observation, and largely in one direction. The trouble may be due in part to the freshet, which rises suddenly in April with the melting snows, and falls off till the end of June or July. Its rise also differs greatly in amount in different years; and it is questionable whether the harmonic terms that are supposed to represent this rise, do so adequately.

The alternative method is to begin with a port in the open estuary below Quebec, where the tide curve is still symmetrical, and may be assumed to be represented accurately by the harmonic constants. From the predictions for this port, the time of the tide at Quebec is then computed by some system of variable tidal differences. This method has also the advantage of dealing in a simple and adequate way with the freshet, as the variation in the general average difference for successive months will cover the freshet effect in retarding the tidal undulation.

Father Point, the Pilot station in the St. Lawrence estuary, was taken as the primary tidal station. The predictions there, are now based on sixteen years of harmonic analysis. It is 180 miles below Quebec, where the estuary is 28 miles wide; and it is within seven miles of the 100-fathom line, and is thus oceanic in its tidal characteristics. The tide curve is still quite symmetrical at Father Point, as shown by the following figures for the duration of the rise and fall of the tide at localities along the estuary:

Quebec	Duration of rise,	5^h	02^m	Duration of fall,	7^h	23^m
Grosse Isle	" "	5^h	22^m	" "	7^h	03^m
Orignaux Point	" "	6^h	00^m	" "	6^h	25^m
Rivière du Loup	" "	6^h	09^m	" "	6^h	16^m
Father Point	" "	6^h	13^m	" "	6^h	12^m

The time which the tidal undulation takes to travel from Father Point to Quebec is approximately 4½ hours for High Water and 5½ hours for Low Water. The average time is subject to variation however, in the three leading lunar periods; which are (1) The Synodic month, from New moon to New moon; the variation from Spring tides to Neap tides recurring in the half month. Its length is 57 half lunar days or tide-intervals. (2) The Anomalistic month of the moon's distance, from Perigee to Perigee; length 53¼ tide intervals. (3) The Declinational month; its length between the moon's successive crossings of the equator in the same direction, being 52¾ tide-intervals.

In the simultaneous observations of the tide at Father Point and

Quebec during five years, the tidal differences were numbered in accordance with these three periods to determine the corresponding variations in the difference of time. In each year, the months of January and February were omitted because of disturbance of normal conditions by ice; and the months of March, April and May were averaged separately to determine the effect of the freshet in the spring. As a rule, the greater depth of water during the freshet increases the rate of travel of the positive undulation at High Water, whereas at Low Water the restricted channel-ways and greater speed of the current due to the additional freshet volume, retard the negative undulation. These effects are manifest in the river above Quebec, as shown by simultaneous observations in the tidal section of the river.

For the computation of High Water at Quebec, the result proved simple. The general average value of the time-difference, after the freshet months, was 4 h. 23 m. and the variation in the value from Springs to Neaps during the Synodic month was only one minute, plus or minus, which is negligible. In the freshet months, the value was 13 m. less than the general average in April and 6 m. less in May. (As early as March, the conditions seemed still to be disturbed; as the averages differed in different years.) As the calculation value for High Water is thus a constant, the lower values in the spring months can readily be allowed for.

For Low Water the general average of the time-difference was 5 h. 37 m. and distinct variation in the value was evident in each lunar month as follows:

Synodic, from Spring to Neaps .....Variation 34^m
Anomalistic, with the Moon's distance .....Variation 18^m
Declinational .....Extreme Variation 19^m

The moon's declination causes a heavy alteration in the successive differences in accordance with its upper and lower transits; and to treat this as a correction would involve a series of plus and minus values alternately, which would be inconvenient. The variation with declination was therefore used as the primary series of differences, which thus become all of one sign; the extreme values in the series being 5 h. 41 m. and 5 h. 23 m. The variations in the Synodic and Anomalistic months are then applied to this series as plus and minus corrections; the correction having the plus sign for quarter or half a month consecutively and the minus sign likewise; which is more convenient than an alternation, and reduces the chances of accidental error in the computation.

In determining these variations, the numbering and tabulation of

the observed time-differences in their respective periods, enabled the three variations to be reduced to the form of curves. From these, the primary values and the two series of corrections were read off in accordance with their respective numberings. In making the computation, the predicted times for Father Point during the coming year are numbered in three series in correspondence with the moon's position, which enables the values and corrections to be applied appropriately; the result affording the desired time of the tide at Quebec.

In investigating the freshet effect upon Low Water, little deviation from the general average was found in the spring months. This appears to result from the considerable depth which extends most of the way from Father Point to Quebec; so that the increase of depth during the freshet months compensated for the increased speed of the river flow against the tidal undulation. Above Quebec, where the depth is less, the time of Low Water is appreciably retarded during the freshet, as compared with other months.

It was therefore assumed in dealing with the Low Water values, that the form and amplitude of the various curves of variation would not be modified in the freshet months, even if the axis of the curve, which represents the general average, were altered in position. The freshet months were accordingly included, to extend the number of months on which the variations were based; making ten in each of the five years with one exception, or 49 months in all.

Correct tide tables for Quebec are unusually important, because the time of the tide at up-river points is derived in turn from them, as far as Lake St. Peter at the head of tide water, 105 miles above Quebec. The crucial point in St. Lawrence navigation is in this stretch, at a point named Cap à la Roche, where rock dredging is still in progress to bring the channel to standard depth. The tide at this point is computed from Quebec by means of two series of differences of time, for High Water and Low Water respectively, in successive months, as the level of the river falls from spring to autumn. In the case of Low Water, the variation during the course of the Synodic month is also allowed for. The computation for time is thus based entirely upon Quebec; the rise of the tide being determined on an independent system.

A test for the accuracy of the method herein described, was based upon the "average error" during the month, between the tide as observed and the time of the tide as predicted or calculated. This average error is the mean amount, irrespective of the plus or minus sign; which affords a consistent comparison.

The Low Water values were used for the test, as calculated for Quebec by the three series of variables, during three months in

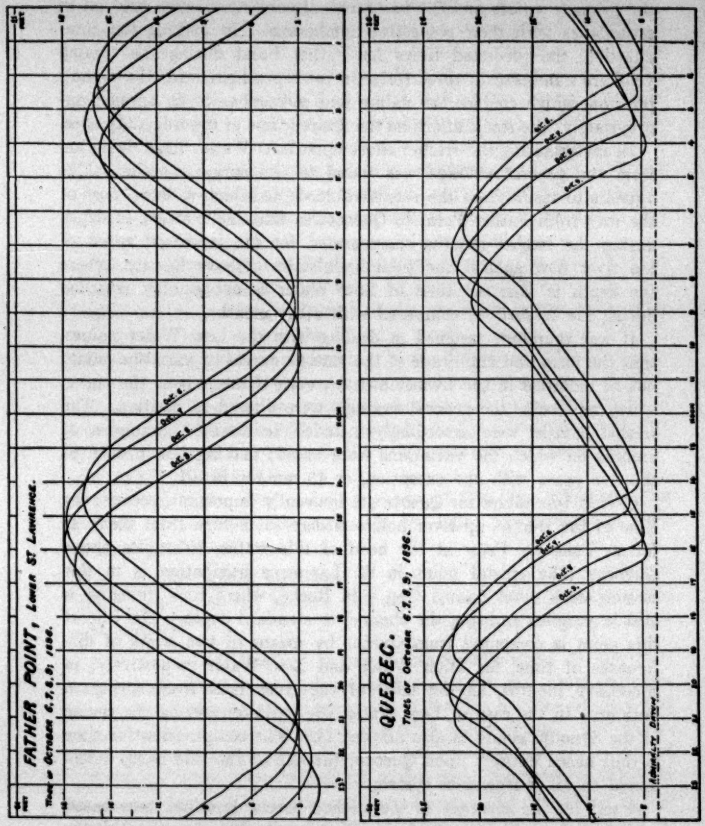

FIGURE 1.—Simultaneous tidal observations at Father Point and Quebec for the period Oct. 6–9, 1896, illustrating the smooth oceanic tidal curve at Father Point and the irregular river tide at Quebec.

1922; the variables being applied to the predictions for Father Point as obtained from the harmonic constants. The improvement obtained, as compared with the harmonic predictions for Quebec, is as follows:

Predictions from Harmonic analysis. Average error in the month, 26 minutes.

Calculation by method explained. Average error in the month, 6 to 8 minutes.

As a further test, the time of Low Water at Quebec was calculated by this method from the time as actually observed at Father Point. The average error in the month was substantially the same as above, namely 6 to 7½ minutes.

The predictions for Father Point, based on fifteen years of harmonic analysis, when compared with the observed time of Low Water there, showed an average error during the month of 6 minutes. The values for Quebec, as given by this method, have thus practically as high an accuracy as the predictions for Father Point itself, on which the calculation for Quebec is based.

The High Water values at Quebec, when calculated by the constant time-difference from Father Point, also show an improvement as compared with the predictions obtained from the harmonic constants for Quebec. The average error during the month, between observed high water and predictions by the harmonic analysis, is 8 to 12 minutes; and by this new method based on Father Point, it is only 4 to 6 minutes. This is remarkably good, when the average error in high water as predicted by the harmonic constants for Father Point itself, is 6 minutes.

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Ottawa, Canada.

SOME RECENT OCEAN HYDROGRAPHY BY THE U. S. COAST AND GEODETIC SURVEY

W. E. Parker

The purpose of this paper is to show that a considerable amount of oceanographic data can be obtained by public vessels at comparatively small cost without seriously interfering with their regular duties and that it is not necessary to defer further exploration of the oceans until such time as well-equipped expeditions can be organized.

During the spring and summer of 1919, and again during the summer and fall of 1922, the U. S. Coast and Geodetic Survey had oc-

casion to transfer several of its surveying vessels from the Atlantic to the Pacific and vice versa.

Advantage was taken of these necessary passages from one coast of the United States to the other to explore the waters through which the vessels were required to pass. Each vessel was required to carry a line of soundings from the port of departure to the port of arrival on the other coast, and each was given a slightly different route so that there would be no duplication of work.

In this way an area of the Atlantic Ocean from Cape Hatteras to the Bahama Islands, 150 to 240 miles wide, of the Caribbean Sea along the steamer route from the Windward Passage to the Panama Canal 120 miles wide, and of the Pacific Ocean from Panama to San Diego, California, 100 to 150 miles wide, was surveyed in considerable detail.

A total of 587 deep sea soundings were taken by the most accurate method known. More than 1,000 temperature observations were taken at the surface, at a depth of 200 fathoms and at the bottom, and several hundred samples of sea water and of bottom material were preserved and forwarded to Washington for analysis.

Some of the most important geographical information obtained by those vessels was, the exact depths over the bank which lies south of Jamaica, proof of the non-existence of the bank supposed to lie about seventeen miles north of Panama, definite location of the Alijos Rocks, and the discovery of a bank midway between Guadaloupe Island and the mainland.

The cost of obtaining all of this data was truly insignificant. Since the vessels were required to make the passages in going to and from their stations, the only expenses which can properly be charged against this work are for special equipment purchased for the work, and for the overhead cost of the vessels, including pay of officials and men for the time required to make the passages in excess of the time which would have been necessary had no survey work been done.

The total time devoted to this work by all of the vessels, six in number, one vessel making the passage twice, was twenty-one days. The total cost of the work, including all expenses, was a little less than $9,000. About 1,000,000 square miles of ocean was explored.

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SECTIONS OF VOLCANOLOGY AND GEOPHYSICAL CHEMISTRY

SYMPOSIUM ON HOT SPRINGS[1]

ROBERT B. SOSMAN

A joint meeting of the Sections of Volcanology and Geophysical Chemistry of the American Geophysical Union was held at the Carnegie Institution of Washington on April 18, 1923, and was devoted to a symposium and discussion on the temperatures of hot springs and the sources of their heat and water supply. Ten papers were presented.

The temperatures of hot springs range all the way from those found in warm springs in the mountains of Virginia, some of which are only slightly above the annual mean temperature, up through boiling springs and mud pots such as are found in our western volcanic regions, to fumarole temperatures of about 650° C., the highest temperature found in the Valley of Ten Thousand Smokes, Alaska, reported on by E. G. Zies in his paper on "Hot Springs and Fumaroles of the Katmai Region."

E. T. Allen, in his paper on "The Hot Springs of Mt. Lassen," showed that chemical reactions, such as could be inferred from the composition of the spring waters, are not adequate to account for more than a very small proportion of the heat. Similarly, radioactivity, so far as it can be inferred from the radioactivity of "The Hot Springs of Iceland," described by F. E. Wright, is also insufficient to supply much heat. The radioactivity shows no parallelism with the temperatures of the springs, as has been shown by Thorkkelsson in Iceland, and by Schlundt and Moore in the Yellowstone.

L. H. Adams discussed "Physical Sources of Heat in Springs," showing that the forced flow of a fluid from a high to a low pressure through a porous plug may develop considerable heat—for liquids, as much as 40° C. for 1000 atmospheres fall. In fact, the passage of any material from a region of high pressure to one of low pressure will usually produce a rise in temperature. Such a process may be a source of heat in rock magmas. G. W. Morey, in his paper on "Relation of Crystallization to the Water Content and Vapor Pressure of Water in a Cooling Magma," showed that similar heat effects could be obtained by the forced flow of steam. These physical sources of heat have not been considered heretofore, and geological observations are lacking to indicate to what extent forced flow is a factor in natural processes.

There seemed to be general agreement, however, in the papers and

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in the discussion, that the source of heat is in subcrustal rock magmas whether it escaped by the familiar processes of conduction and convection, or whether the process of flow played an important part. C. E. Van Orstrand, in his paper on "Temperatures in Some Springs and Geysers in Yellowstone National Park," estimated from temperatures in deep borings that most of the heat might be coming from depths between 3400 and 8000 ft.

Agreement was not so general as to the sources of the water supply. In the Yellowstone, as described by Van Orstrand, a considerable proportion of the water must be meteoric—that is, from rain and snow. The same is probably true in Iceland, where there is a large supply from snow fields and glaciers. Allen believes that the probability is strong that over half of the water in the springs of Mt. Lassen is from such sources, and A. L. Day showed that the water of "The Hot Springs of 'The Geysers' Region of California" is also mainly meteoric.

On the other hand, it was brought out in the discussion that the amount of water which may be dissolved in a batholithic magma of the chemical character described by Morey may be sufficient to supply small hot springs for hundreds of thousands of years without any addition of surface water, and Morey also showed that the conditions of crystallization of such a magma may yield water vapor under considerable pressure. It seems very reasonable to suppose that a considerable proportion of the water in such places as "The Hot Springs of Vulcano and Kalamaki," described by H. S. Washington, might be original magmatic water. This seems almost a necessary conclusion for some of "The Hot Springs of Southern Idaho," described by O. E. Meinzer. It was shown very clearly in the paper by Meinzer that there is no artesian source of water for many of the springs. It was also shown that on the whole the hotter springs are the smaller, indicating that dilution with ground water from moderate depths is responsible at the same time for low temperature and large volume. These springs come through Paleozoic rocks, Cretaceous granite, etc., and have no direct relation to the Snake River basalts, which are now quite cold.

A paper by Kirk Bryan on "The Hot Springs of Arkansas" was presented only by title as Mr. Bryan had to be absent on field work.

The publication in full of the papers and discussion is being considered. If they are so published it will be possible to add several other papers on other hot-spring areas of the United States, as well as communicated discussion, which will make this a valuable summary of the present status of our information on the subject.

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